RNI No. 34518/79
ISSN 0537-197X
Online ISSN 0974-4460

INDIAN JOURNAL OF AGRONOMY

December 2023 Volume 68 No. 4

THE INDIAN SOCIETY OF AGRONOMY
ICAR-Indian Agricultural Research Institute, New Delhi 110 012
website: www.isa-india.in Online: www.pub.isa-india.in

THE INDIAN SOCIETY OF AGRONOMY

(Founded in 1955)

Executive Council for 2022 and 2023

Councillors

Mandate of the Society

1. **To disseminate knowledge of Agronomy**
2. **To encourage research in the field of soil, water and crop management**
3. **To provide suitable forum for exchange of ideas to research workers**

INDIAN JOURNAL OF AGRONOMY

Indian Journal of Agronomy, the official journal of the Indian Society of Agronomy, is published quarterly in the month of March, June, September and December since 1956. The journal publishes papers based on the results of original research in following areas:

i. **Crop production and management**
ii. **Soil-water-plant relationship**
iii. **Cropping and farming system research**
iv. **Agro-ecosystems and environment management**
v. **Other areas of agronomy research and**
vi. **Invited review papers**

Indian Journal of Agronomy is indexed in the AGRIS, published by the FAO, the Science Citation Index (SCI) and Current Contents (Agriculture, Biology and Environmental Sciences) published by the Institute of Scientific Information (ISI), Philadelphia. It is also indexed in the abstraction journals of the Centre for Agriculture and Biosciences International (CABI) as well as all the major abstracting services of the world.

Membership and Journal Subscription

	Subscription price revised rate w.e.f. from 1^{st} January 2023		
	Annual		**Life**
A. **Individual Membership**			
Indian (₹)	2,500 (1500*)		12,000
Foreign (US $ or its equivalent)	250 (150*)		1,500
*For Students			
B. **Libraries and Institutions (Annually)**	**Print**	**Online**	**Print+Online**
Indian (₹)	7,500	7,500	10,000
Foreign (US $ or its equivalent)	750	750	1,000

Payment should be made by Demand Draft in favour of SECRETARY, INDIAN SOCIETY OF AGRONOMY payable at New Delhi. Back Volumes of the journal, symposia proceedings and books are available for sale.

NEFT transactions details: Beneficiaries Name Indian Society of Agronomy; Saving Bank Account No. 91212010007024 Bank & Branch Name CANARA BANK (NSC Branch) IFSC Code: CNRB0019121, MICR Code: 110015429, Swift Code: CNRBINBBBFD; Bank Address and Phone Number National Seeds Corporation, Beej Bhavan, Pusa Campus, New Delhi 110 012, Ph. No. 011-25848197.

All Correspondence may please be addressed to Secretary, Indian Society of Agronomy, Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi 110 012. Telephone: 011-25842283; 09717078548; E-mail: secretary_isa@hotmail.com; Visit Society Website: isa-india.in for author guidelines and other information.

INDIAN JOURNAL OF AGRONOMY

December 2023 Volume 68 No. 4

Contents

(*Continued*)

Indian Journal of Agronomy **68** (4): 343–350 (December 2023)

Research Paper

Organic farming practices in rainfed lowland rice in Hill Zone of Karnataka, India

K. MANJAPPA[1]

Agricultural Research Station on Paddy, University of Agricultural Sciences, Sirsi, Karnataka 581 401

Received: December 2021; Revised accepted: October 2023

ABSTRACT

A large-scale field trial was conducted at Agricultural Research Station (Paddy), Sirsi of the University of Agricultural Sciences, Sirsi, Karnataka, India, during 2004–15 on a fixed site, to study the effect of different organic farming practices on productivity of rice (*Oryza sativa* L.) under inorganic and integrated nutrient-management practices. The trial consisted of 5 treatments, viz. T_1, Organic [75% N through organic manures + 100% organic plant protection (PP) measures]; T_2, organic [100% N through organic manure + 100% organic plant protection (PP) measures]; T_3, integrated nutrient management [50% N through organic manures + 50% RDF + integrated PP measures]; T_4, inorganic treatment [recommended dose of fertilizers (RDF) alone + inorganic PP measures]; and T_5, recommended practice (RDF + FYM 10 t/ha + integrated PP measures). The rice variety 'Abilash' was grown during the rainy (*kharif*) season with these treatments. At the end of 12th year, i.e. during 2015, the grain yield recorded in treatment T_2 (6.418 t/ha) was the maximum and was found on a par with T_5 (6.328 t/ha). How-ever, the straw yield was the maximum in T_5 (7.577 t/ha), being at par with T_2 (7.494 t/ha). The net returns realized were significantly highest with treatment T_2 (₹41,045/ha) compared to all the other treatments. The soil organic carbon (0.77%), available major (221.2, 22.0 and 67.0 kg/ha of N, P and K, respectively) and micro-nutrients (515.5, 100.8, 5.6 ppm of calcium, magnesium and zinc, respectively and 7.6 kg/ha of sulphur) were also higher with treatment T_2.

Key words: Eupatorium, Lowland Rice, Organic farming, RDF, Soil fertility

Rice (*Oryza sativa* L.) is the most important food crop, occupying about 43.7 million ha area and contributing about 41.7% of the total foodgrain production in India (MoA&FW, 2020). In hill zone of Karnataka, rice is the major crop grown under rainfed situation. The productivity of rice is lower in the hill zone as compared to the state average. Hence, the conventional rice farming has been oriented towards enhancing rice yield by encouraging inorganic fertilizer and pesticides. Though the dosage of fertilizer had been increased, crop productivity was not in balance with supplying additional fertilizer. Further, the dependence on higher doses of chemical fertilizers and pesticides potentially reduced the soil organic carbon and mineral nutrients (Prakash *et al*., 2008) and resulted in reduced land productivity (Patil, 2008). This emerging scenario necessitates the need of adoption of the practices which maintains soil health, and provides qualitative food for meeting the nutritional requirements. Organic farming is one of the practices to make the production system more sustainable without adverse effects on the natural resources and the environment (Stockdale *et al*., 2001; Debjani Sihi *et al*., 2017). The research on organic farming in rice is directed towards a complete or partial substitution of chemical fertilizers with organic fertilizers to enhance rice yield. But, no one source of nutrient usually suffices to maintain productivity and quality control in organic system. In addition, the inputs to supplement nutrient availability are often not uniform presenting additional challenges in meeting the nutrient requirement of crops in organic farming (Singh *et al*., 2007). Keeping these in view, a large-scale field experiment was conducted to find out a suitable organic farming practice for rainfed lowland rice grown under transplanted situation.

MATERIALS AND METHODS

A large-scale field trial was conducted at Agricultural Research Station (Paddy), Sirsi, of the University of Agricultural Sciences, Dharwad, Karnataka, India, during 2004–15 on a fixed site. The experimental site is situated in the hill zone (Zone - 9) of Karnataka which comes

[1]**Corresponding author's Email:** manjappasirsi@gmail.com
[1]Professor of Agronomy and Head, Agricultural Research Station (Paddy), Sirsi, Karnataka 581 401

under high-rainfall situation. The site is located between 14º 37' 12.06'' N and 74º 50' 60.09'' E. Average annual rainfall of 12 years (2004 to 2015) was 2,142 mm, highest maximum temperature was 35.3ºC during April and minimum temperature 14.0ºC during January. The soil was sandy clay loam.

The experiment was laid out in randomized complete-block design (RCBD) with 5 treatments, viz. T_1, organic [75% recommended dose of nitrogen (RDN) through organic manures + 100% organic plant protection (PP) measures]; T_2, organic (100% RDN through organic manure + 100% organic PP measures); T_3, integrated nutrient management [50% RDN through organic manures + 50% recommended dose of fertilizer (RDF) + integrated PP measures); T_4, inorganic treatment (RDF alone + inorganic PP measures); and T_5, recommended package of practice (RDF + FYM 10 t/ha + integrated PP measures) and replicated 4 times. Each treatment was imposed in 500 m^2 area. To make observations on crop yield, plot size of 5 m × 5 m was marked in each treatment at 5 different spots randomly. The details of practices followed in different treatments including plant-protection measures are given in Table 1. Eupatorium (*Chromolaena odorata*), an obnoxious weed found in abundance in the region whose nitrogen is quite comparable to other conventional green/green-leaf manures (Manjappa, 1999) was used as green-leaf manure to supply required recommended dose of nitrogen in different treatments. The quantity of eupatorium was derived based on its nitrogen and moisture content in each year. The quantity of organic manures used and their nutrient content are given in Table 2. The organic manures were incorporated every year into the soil 2 weeks before planting as per the treatments.

A long-duration (155 days) rice variety 'Abilash' was used. For planting, 30-day-aged seedlings were used, and 2–3 seedlings were planted at each hill. The fertilizers were applied in accordance with the treatments. Recommended dose of fertilizer used was 75 kg N, 75 kg P_2O_5 and 87.5 kg K_2O/ha (UAS, 2004). At the time of planting, 50% each of N and K_2O and entire dose of P_2O_5 were applied. Remaining 50% of N and K_2O were given in 2 equal split doses as top-dressing at 25 and 50 days after planting (DAP).

Observations on grain and straw yield were made at harvesting of crop each year and economics was worked out based on the prevailed market prices of both input and output during each year of experimentation. Before the start of the experiment, initial composite soil sample was collected, processed, and analysed for organic carbon and available major (N, P and K) and micro (Zn, Cu, Mn and Fe) nutrients. At the end of 12th year, the soil samples were collected from individual treatments after the harvesting of rice crop and were analysed for organic carbon and available major nutrients. The data were analysed statistically as per the RCBD design under M-STAT-C programme.

RESULTS AND DISCUSSION

Grain and straw yield

During the first year of experimentation, the highest grain yield was recorded with recommended package of practice (RPP) treatment (5.353 t/ha) followed by integrated practices (5.126 t/ha) and 100% organic practice (4.835 t/ha) and both were found at par (Table 3). Our results confirm the findings of Singh and Dhar Dolly (2011). The lowest grain yield was recorded with 75% organic treatment (4.110 t/ha). During 2015 (12th year), the maximum grain yield was observed in 100% organic treatment (6.418 t/ha), being at par with RPP treatment (6.328 t/ha). The grain yield obtained with INM (50% organic + 50% inorganic) treatment (5.433 t/ha) was at par with that of inorganic treatment (5.434 t/ha). The significantly lower yield was recorded with 75% organic treatment. The same trend was also noticed in pooled data. In general, the grain yield was the maximum with RPP treatment compared to 100% organic treatment during initial 6 years only (2004 to 2009). Thereafter, the grain yield was found maximum with 100% organic treatment where eupatorium green-leaf manure was used to supplement 100% RDN as compared to RPP treatment in all the years except during 2006 and 2007. The beneficial effect of green-leaf manure may be because of its capacity to supply nitrogen in addition to their solubilizing effect on native soil nutrients owing to the action of organic acids produced during decomposition (Pandey *et al.,* 2007; Tripathi *et al*., 2009). This is evident from the data on N, P and K content of eupatorium in different years of experimentation which was higher in eupatorium compared to FYM (Table 2). The superiority of green-manure to FYM in increasing the productivity of rice was also reported by Moola Ram *et al*. (2011) and Tao Li *et al*. (2019). Further, the study clearly indicates that it took nearly 6 years (except second year) to stabilize the rice yield in 100% organic treatment.

The straw yield recorded with RPP treatment was signicantly higher than all the other treatments during first 4 years (2004 to 2007) of experimentation. From 2012 (9th year) onwards, 100% organic treatment resulted in the maximum straw yield compared to RPP treatment (Table 4). However, the differences were non-significant, indicating improvement in grain yield in 100% organic treatment only after 4 years of continuous application of green-leaf manure. At 12th year of experimentation (2015), 100% organic treatment recorded the maximum straw yield (7.694 t/ha) which was on par with RPP treatment (7.577 t/ha). The straw yield obtained with INM (50% organic + 50% inorganic) treatment (6.042 t/ha) and inorganic treat-

Table 1. Details of practices followed in different treatments of the experiment

Treatment	Practices followed			
	Fertilizer	Organic / green-leaf manure	Biofertilizers	Plant protection (PP) measures
T_1, Organic [75% N through organic manures + 100% organic plant protection (PP) measures]	–	Eupatorium to supplement 75% RDN	*Azospirullum* + PSB seedling dip	1 spray of *Pseudomonos fluroscence* (10 ml/litre) 1 spray of *mukkadaka** extract for leaf folder
T_2, Organic (100% N through organic manure + 100% organic PP measures)	–	Eupatorium to supplement 100% RDN	*Azospirullum* + PSB seedling dip	1 spray of *Pseudomonos fluroscence* (10 ml/litre) 1 spray of *mukkadaka* extract for leaf folder
T_3, Integrated nutrient management (50% N through organic manures + 50% RDF + integrated PP measures)	50% RDF	Eupatorium to supplement 50% RDN	*Azospirullum* + PSB seedling dip	1 spray of *Pseudomonos fluroscence* (10 ml/litre), 1 spray of tricyclozole @ 0.6 g/litre, 1 spray of *mukkadaka* extract for leaf folder 1 spray of chloropyriphos (2 ml/litre)
T_4, Inorganic treatment (RDF alone + Inorganic PP measures)	100% RDF	–	–	Seed treatment with bavistin (2 g/kg) 1 spray of tricyclozole @ 0.6 g/litre 1 spray of *mukkadaka* extract for leaf folder 1 spray of chloropyriphos (2 ml/litre)
T_5, Recommended practice (RDF + FYM 10 t/ha + integrated PP measures)	100% RDF	FYM (10 t/ha)	*Azospirullum* + PSB seedling dip	Seed treatment with bavistin (2 g/kg) 1 spray of tricyclozole @ 0.6 g/litre 1 spray of chloropyriphos (2 ml/litre)

RDN, Recommended dose of nitrogen; PSB, phosphate-solubilizing bacteria; RDF, recommended dose of fertilizer; **Pterospermum acerifolium* (L.) Willd.

Table 2. The quantity of eupatorium used, and its nitrogen and moisture content and nitrogen added by farmyard manure applied in different years of experimentation

Particulars	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nitrogen content (%) of eupatorium on dry weight basis	1.82	2.55	1.77	1.52	2.22	1.95	1.87	2.02	1.86	1.87	1.92	1.95
Phosphorus content (%) of eupatorium on dry weight basis	0.19	0.23	0.19	0.17	0.22	0.20	0.18	0.21	0.20	0.21	0.22	0.19
Potassium content (%) of eupatorium on dry weight basis	2.18	2.34	1.98	1.77	2.32	1.96	1.92	2.01	2.04	1.99	2.01	2.00
Moisture content (%)	74.2	78.1	75.4	73.2	75.4	74.1	75	73.3	75.1	74.1	74.7	75.6
Quantity of fresh eupatorium used (kg/ha) in T_1 (75% RDN)	11,979	10073	12,919	13808	10300	11138	12032	10429	12145	11614	11580	11822
Quantity of fresh eupatorium used (kg/ha) in T_2 (100% RDN)	15,972	13430	17,225	18411	13733	14850	16043	13906	16194	15485	15440	15763
Quantity of fresh eupatorium used (kg/ha) . in T_3 (50% RDN)	7,986	6715	8612	9206	6867	7425	8021	6953	8097	7743	7720	7881
Nitrogen content of FYM (%)	0.97	0.95	0.95	0.98	0.85	0.92	0.88	0.95	0.89	0.85	0.86	0.87
Phosphorus content of FYM (%)	0.43	0.39	0.41	0.40	0.39	0.41	0.38	0.42	0.39	0.38	0.39	0.40
Potassium content of FYM (%)	0.21	0.22	0.19	0.20	0.18	0.20	0.17	0.21	0.19	0.17	0.17	0.19
Moisture content (%)	46.2	45.8	46.0	47.1	42.0	45.6	45.8	43.4	43.2	45.2	46.1	42.0
Amount of N added (kg) by FYM (10 t/ha)	52.2	51.5	51.3	51.8	49.3	50.0	47.7	53.8	50.6	46.6	46.4	50.5

RDN, recommended dose of nitrogen

Table 3. Effect of organic farming treatments on grain yield of rainfed transplanted rice

Treatment	Grain yield (t/ha)												
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Pooled
T_1, 75% organic	4.110$^{c\#}$	4.746^{c}	3.801^{c}	4.514^{c}	4.536^{b}	2.572^{c}	4.387^{b}	3.978^{c}	4.439^{c}	4.420^{c}	4.673^{c}	4.095^{c}	4.189^{c}
T_2, 100% organic	4.835^{ab}	6.157^{a}	5.240^{b}	5.415^{b}	5.088^{ab}	3.553^{a}	6.138^{a}	5.631^{a}	6.238^{a}	6.451^{a}	6.304^{a}	6.418^{a}	5.622^{a}
T_3, INM (50 + 50%)	5.126^{a}	5.394^{b}	4.627^{b}	4.747^{c}	4.788^{ab}	3.737^{bc}	5.517^{a}	5.359^{ab}	4.571^{c}	4.876^{b}	5.040^{b}	5.433^{b}	4.935^{b}
T_4, Inorganic	4.552^{b}	5.893^{b}	5.152^{b}	5.488^{ab}	4.321^{c}	2.695^{bc}	5.733^{a}	4.547^{b}	4.855^{b}	5.582^{b}	5.483^{b}	5.434^{b}	4.978^{b}
T_5, RPP	5.353^{a}	6.112^{a}	5.996^{a}	5.941^{a}	5.394^{a}	2.454^{b}	6.047^{a}	5.575^{a}	5.134^{b}	6.123^{a}	5.784^{a}	6.328^{a}	5.465^{a}
SEm±	0.146	0.149	0.205	0.158	0.244	0.129	0.289	0.188	0.175	0.267	0.271	0.280	0.660
CD (P=0.05)	0.438	0.447	0.615	0.474	0.732	0.387	0.866	0.563	0.526	0.799	0.811	0.838	0.183

Details of treatments are given in Table 1, #, means followed by same letters in a column are not differing significantly

Table 4. Straw yield of rainfed transplanted rice as influenced by organic farming treatment

Treatments	Straw yield (t/ha)												
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Pooled
T_1, 75% organic	4.700$^{c\#}$	4.480^{d}	4.494^{d}	5.106^{c}	5.701^{b}	5.613^{c}	7.086^{c}	4.510^{b}	5.280^{c}	4.508^{c}	5.836^{b}	4.512^{c}	5.152^{c}
T_2, 100% organic	5.625^{b}	6.277^{bc}	6.007^{b}	5.783^{b}	6.910^{a}	7.061^{a}	7.796^{b}	6.096^{a}	8.361^{a}	6.990^{a}	7.357^{a}	7.694^{a}	6.830^{a}
T_3, INM (50 + 50%)	5.543^{b}	5.871^{c}	5.139^{cd}	5.348^{b}	5.599^{b}	6.003^{bc}	8.789^{a}	5.614^{ab}	5.726^{bc}	5.806^{b}	5.950^{b}	6.042^{b}	5.953^{b}
T_4, Inorganic	5.909^{b}	6.679^{b}	5.701^{bc}	5.783^{b}	5.690^{b}	5.966^{bc}	9.370^{ab}	5.210^{b}	5.737^{bc}	6.606^{a}	7.228^{a}	6.443^{b}	6.360^{b}
T_5, RPP	7.765^{a}	7.787^{a}	7.097^{a}	7.209^{a}	7.328^{a}	6.376^{b}	9.477^{a}	6.131^{a}	6.100^{b}	6.512^{ab}	7.425^{a}	7.577^{a}	7.232^{a}
SEm±	0.130	0.213	0.266	0.197	0.305	0.167	0.535	0.236	0.1,97	0.257	0.266	0.189	0.163
CD (P=0.05)	0.390	0.639	0.798	0.594	0.914	0.501	0.160	0.709	0.589	0.771	0.798	0.568	0.451

Details of treatments are given in Table 1, #, means followed by same letters in a column are not differing significantly ment (6.443 t/ha) were at par. The 75% organic treatment resulted in significantly lower yield. Similar trend in straw yield was noticed in the pooled data of 12 years also.

These results clearly indicate that, it was possible to get rice yield equivalent to RPP by practicing organic farming where the 100% of RDN was substituted by green-leaf manure, viz. eupatorium. Further, results indicated that the transition period in this organic practice was from 6th year under assured rainfall situation of hill zone of Karnataka. Instances of getting higher and sustainable yield of rice by farmers who adopted organic farming as compared to conventional farming were reported by Sihi Oebjani *et al*. (2012) and Eyhorn *et al*. (2018).

Economics

Net returns realized in different organic farming treatments was showed almost similar to that of straw yield. The net returns were the maximum with RPP treatment up to 2010 (first 7 years of study). However, it was on par with 100% organic treatment in all these years except during 2009. From 8th year (2011) onwards, the net returns realized with 100% organic treatment were significantly higher than all the other treatments (Table 5). This might be owing to the influence of continuous addition of green-leaf manure in this treatment. Moola Ram *et al*. (2011) also reported superiority of green-manure to FYM in increasing net income of rice. During the last 5 years (2012 to 2015), the treatments, viz. INM, inorganic treatment and RPP treatment, were found at par with respect to net returns. Benefit: cost (B : C) ratio (Table 6) was also significantly higher in 100% organic treatment (3.31) compared to all other treatments during 2015 as well as in pooled data (2.56). The lower net returns and B : C ratio with RPP treatment than 100% organic treatment was mainly due to increased cost of inorganic plant-protection measures. Teodoro Mendoza (2004) also reported increased cost of cultivation in conventional farming due to increased cost of agro-chemical inputs as compared to organic farming.

Soil-nutrient content

In general, there was an improvement in soil-nutrient content in treatments where green-leaf manure or FYM was used as compared to their respective initial values (Table 7). The initial organic carbon content was 0.30–0.34% in different treatments. At the end of the study (2015), the organic carbon content of rice soil was the maximum in 100% organic treatment (0.77%) followed by 75% organic treatment (0.70) and RPP treatment (0.69%). Yadav *et al.* (2009); Singh and Dhar Dolly (2011) and Rao *et al*. (2014) also reported improvement in soil organic carbon content due to organic farming over control as well as chemical fertilizer application. The lower organic carbon

Table 5. Organic farming treatments on economics (Net returns) of rainfed transplanted rice

Treatment	Net Returns (₹/ha)												
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Pooled
T_1, 75% organic	14,083$^{c\#}$	17,293c	11,827^{d}	19,858^{b}	33,228^{b}	10,118^{b}	30,481^{b}	15,165^{d}	37,752^{b}	35,646^{c}	43,851^{b}	31,099^{c}	25,033^{d}
T_2, 100% organic	18,746^{ab}	27,199a	21,490^{ab}	26,025^{a}	38,485^{a}	21,159^{a}	35,101^{ab}	33,114^{a}	67,845^{a}	68,081^{a}	66,671^{a}	68,625^{a}	41,045^{a}
T_3, INM (50 + 50%)	19,752^{a}	21,406b	16,079^{c}	20,353^{b}	34,989^{b}	18,363^{a}	40,343^{ab}	26,641^{ab}	34,954^{b}	40,255^{b}	41,961^{b}	47,651^{b}	30,396^{c}
T_4, Inorganic	16,168^{bc}	24,961a	19,493^{bc}	25,378^{a}	34,875^{b}	10,184^{b}	45,677^{a}	18,464^{cd}	38,844^{b}	53,563^{b}	53,412^{b}	48,362^{b}	32,448^{bc}
T_5, RPP	22,221^{a}	25,562a	24,062^{a}	28,033^{a}	35,762^{ab}	24,640^{c}	43,053^{a}	24,411^{bc}	37,769^{b}	52,423^{b}	49,512^{b}	57,431^{b}	33,559^{b}
SEm±	1,163	1,047	1,401	1,172	1,055	1,312	3,411	2,131	2,674	4,067	3,859	3,628	774
CD (P=0.05)	3,489	3,141	4,203	3,465	3,165	3,933	102,25	6,390	8,016	12,193	11,570	10,877	2,145

Details of treatments are given in Table 1; #, means followed by same letters in a column are not differing significantly

Table 6. Benefit: cost ratio of rainfed transplanted rice as influenced by organic farming treatments

Treatment	Benefit: cost ratio												
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Pooled
T_1, 75% organic	$1.90^{d\#}$	2.16^{d}	1.76^{c}	2.27^{b}	2.61^{b}	1.42^{b}	2.27^{b}	1.48^{c}	2.07^{b}	$2.01b^{c}$	2.24^{b}	2.14^{c}	2.03^{c}
T_2, 100% organic	2.20^{bc}	2.66^{a}	2.33^{a}	2.62^{a}	2.69^{b}	1.85^{a}	2.41^{ab}	2.02^{a}	2.87^{a}	2.88^{a}	2.85^{a}	3.31^{a}	2.56^{a}
T_3, INM (50 + 50%)	2.27^{b}	2.26^{c}	1.95^{bc}	2.20^{c}	2.64^{b}	1.62^{ab}	2.44^{ab}	1.75^{b}	1.86^{c}	1.97^{c}	2.04^{b}	2.48^{b}	2.12^{bc}
T_4, Inorganic	2.04^{cd}	2.45^{b}	2.13^{ab}	2.47^{ab}	3.07^{a}	1.40^{bc}	2.78^{a}	1.53^{c}	1.96^{bc}	2.32^{b}	2.32^{b}	2.51^{b}	2.25^{b}
T_5, RPP	2.42^{a}	2.33^{bc}	2.25^{a}	2.45^{ab}	2.23^{c}	1.11^{c}	2.36^{b}	1.60^{bc}	1.81^{c}	2.13^{bc}	2.07^{b}	2.57^{b}	2.11^{bc}
SEm±	0.0584	0.0565	0.0838	0.0686	0.1082	0.0991	0.1248	0.0574	0.0674	0.1095	0.098	0.1072	0.0520
CD (P=0.05)	0.1752	0.1690	0.2510	0.206	0.324	0.297	0.374	0.1720	0.202	0.328	0.293	0.321	0.1441

Details of treatments are given in Table 1; #, means followed by same letters in a column are not differing significantly

Table 7. Organic carbon and major nutrients of soil as influenced by different organic farming treatments

Treatment	Organic carbon (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	Initial (May 2004)	After harvesting of rice (December 2015)	Initial (May, 2004)	After harvesting of rice (December 2015)	Initial (May 2004)	After harvesting of rice (December 2015)	Initial (May 2004)	After harvesting of rice (December 2015)
T_1, 75% organic	0.31	0.69	184.8	207.2	12.9	20.0	35.4	60.0
T_2, 100% organic	0.34	0.77	165.2	221.2	11.6	22.0	33.0	67.0
T_3, INM (50 + 50%)	0.31	0.60	182.0	212.8	12.1	16.5	37.2	59.0
T_4, Inorganic	0.30	0.57	170.8	204.4	12.5	20.5	37.2	62.0
T_5, RPP	0.32	0.69	179.4	212.8	13.1	21.5	38.5	62.0

Details of treatments are given in Table 1

Table 8. Secondary nutrients of soil as influenced by different organic farming treatments

Treatment	Calcium (ppm)		Magnesium (ppm)		Sulphur (kg/ha)		Zinc (ppm)	
	Initial (May, 2004)	After Harvesting of rice (December 2015)	Initial (May, 2004)	After Harvesting of rice (December 2015)	Initial (May, 2004)	After Harvesting of rice (December 2015)	Initial (May, 2004)	After Harvesting of rice (December 2015)
T_1, 75% Organic	320.2	445.2	60.5	96.2	21.9	16.7	1.8	4.3
T_2, 100% Organic	330.3	515.5	59.2	100.8	22.2	17.6	1.7	5.6
T_3, INM (50 + 50%)	329.5	584.6	57.8	93.7	19.9	14.1	1.8	3.6
T_4, Inorganic	325.5	539.1	58.9	96.3	22.1	23.2	1.7	4.1
T_5, RPP	327.2	595.4	58.1	90.4	21.7	28.0	1.8	4.8

Details of treatments are given in Table 1

content was recorded in inorganic treatment (0.57). The improvement in organic carbon content in these treatments was mainly attributed to continuous use of eupatorium or FYM. The status of available nitrogen, phosphorus and potassium content of soil also indicated improvement in treatments where greenleaf manure or FYM was used as compared to inorganic treatment. The available nitrogen (221.2 kg/ha), phosphorus (22.0 kg/ha) and potassium (67.0 kg/ha) contents were maximum with 100% organic treatment. Debjani Sihi *et al*. (2017) reported similar results, indicating improvement in soil organic carbon and nutrient content owing to long-term application of organic manures in certified organic farms as compared to conventional farms.

It can be concluded that, continuous application of eupatorium green-leaf manure to supply recommended dose of nitrogen and practicing all plant-protection measures organically found to give equivalent rice yield and net returns as that of recommended package of practices from 6th year onwards.

REFERENCES

Debjani Sihi, Biswanath Dari, Dinesh K. Sharma, Himanshu Pathak, Lata Nain and Om Parkash Sharma. 2017. Evaluation of soil health in organic vs. conventional farming of basmati rice in North India. *Journal of Plant Nutrition and Soil Science* **180**(3): 389–406.

Eyhorn, F., Van den Berg, M., Decock, C. and Maat, H. 2018. Does organic farming provide a viable alternative for smallholder rice farmers in India? *Sustainability* **10**(12): 4,424.

Manjappa, K. 1999. Sustainable production of planted and ratoon crop of hybrid rice under hill zone of Kanataka. Ph.D. thesis, University of Agricultural Sciences, Dharwad, Karnataka, India (unpublished).

MoA & FW. 2020. *Agricultural Statistics at a Glance 2019*. Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, Government of India, New Delhi p. 48.

Moola Ram, Devari, M.R. and Sharma, S.N. 2011. Effect of organic manures and biofertilizers on basmati rice (*Oryza sativa* L.) under organic farming of rice–wheat cropping system. *International Journal of Agriculture and Crop Sciences* **3**(3): 76–84.

Pandey, N., Verma, A.K., Anurag and Tripathi, R.S. 2007. Integrated nutrient management in transplanted hybrid rice. *Indian Journal of Agronomy* **52**(1): 40–42.

Patil, V.C. 2008. Declining factor productivity and improving nutrient-use efficiency. (In) *Proceedings of the National Symposium on New Paradigms in Agronomic Research,* held during 19–21, November 2008 at Navasari, Gujarat, India.

Prakash, Anand, Singh, V.P., Kumar, Rajeev and Singh, I.P. 2008. Effect of organics and micronutrient fertilization in rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) cropping system. (In) *Proceedings of the National Symposium on New Paradigms in Agronomic Research,* held during 19–21 November 2008, Navasari, Gujarat, India.

Rao, A.U., Murthy, K.M.D., Sridhar, T.V., Raju, S.K. and Lakshmi, D.A. 2014. Studies on performance of organic farming and chemical farming in rainy season rice. *International Journal of Plant, Animal and Environmental Sciences* **4**(4): 202–206.

Sihi Oebjani, Sharma, O.K., Pathak, H., Singh, V.V., Sharma, C.P., Lata, Chaudhary, A. 2012. Effect of organic farming on productivity and quality of basmati rice. *ORYZA- An International Journal on Rice* **49**(1): 24–29.

Singh Y.V. and Dhar Dolly, W. 2011. Influence of organic farming on soil microbial diversity and grain yield under rice–wheat–green gram cropping sequence, *ORYZA–An International Journal on Rice* **48**(1): 40–46.

Singh, Y.V., Singh, B.V., Pabbi, S. and Singh, P.K. 2007. *Impact of Organic Farming on Yield and Quality of Basmati Rice and Soil Properties*. (http://orgprints.org/view/projects/wissenschaftstagung-2007.html)

Stockdale, E.A., Lampkin, N.H., Hovi, M., Keating, R., Lennartsson, E.K.M., Macdonald, D.W., Padel, S., Tattersall, F.H., Wolfe, M.S. and Watson, C.A. 2001. Agronomic and environmental implications of organic farming systems. *Advances in Agronomy* **70**: 261–327.

Tao Li, Jusheng Gao, Lingyu Bai, Yanan Wand, Jing Huang, Mahendar Kumar and Xibai Zeng. 2019. Influence of green manure and rice straw management on soil organic carbon, enzyme activities, and rice yield in red paddy soil. *Soil and Tillage Research* **195**: 104–428.

Teodoro, C. and Mendoza. 2004. Evaluating the benefits of organic farming in fice agroecosystems in the Philippines. *Journal of Sustainable Agriculture* **24**(2): 93–115.

Tripathi, M.K., Majumdar, B., Sarakar, S.K., Chowdhary, H. and Mahapatra, B.S. 2009. Effect of integrated nutrient management on sunnhemp (*Crotalaria juncea*) and its residual effects on succeeding rice (*Oryza sativa*) in eastern Uttar Pradesh. *Indian Journal of Agricultural Sciences* **79**(9): 694–698.

UAS. 2004. *Package of Practices for High Yields*. University of Agricultural Sciences, Dharwad, Karnataka, India.

Yadav, D.S., Kumar Vineet and Yadav, Vivek. 2009. Effect of organic farming on productivity, soil health and economics of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system. *Indian Journal of Agronomy* **54**(3): 267–271.

Indian Journal of Agronomy 68 (4): 351–356 (December 2023)

Research Paper

Effect of conjoint application schedules of organic and inorganic sources of nutrients on growth, yield and economics of rice

SHAKTI OM PATHAK[1], B.P. DHYANI[2], NIDHI LUTHRA[3], U.P. SHAHI[4] AND GAURAV SHUKLA[5]

Received: December 2022; Revised accepted: November 2023

ABSTRACT

A field experiment was conducted during (*kharif)* summer season of 2019 and 2020 at Crop Research Centre, Sardar Vallabh Bhai Patel University of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh to study the effect of integrated use of chemical nitrogen fertilizer and green manure on performance of rice (*Oryza sativa* L.). The experiment consists of fourteen treatment combinations of conjoint application of organic and inorganic sources of nutrients was laid-out in randomized block design with three replications. The results showed that the significant highest dry matter accumulation (1,205.90 g/m^2) at harvest stage, leaf-area index (4.18), crop growth rate (16.34 g/m^2/day), relative growth rate (7.09 mg/g/day), grain yield (3.88 t/ha) and straw yield (6.64 t/ha) recorded in the 25% recommended N through *dhaincha* incorporated + 75% N through chemical fertilizer was found at par with RDF (120N : 60P : 50K) and 25% recommended N through vermicompost incorporated 10 days before transplanting + 75% N through chemical fertilizer and it was significantly superior over rest of the treatment combinations. The substitution of 25% N through incorporated *dhaincha* at planting was found most promising in terms of productivity, profitability and performed better than other treatments and may be recommended for farmers of Uttar Pradesh and similar agro-eco regions.

Key words: Economics, growth parameters, rice, ntegrated, yield

Rice (*Oryza sativa* L.) is one of the world's most consumed cereal crops. 'Rice is life' is the most appropriate statement for India since this crop plays a vital role in country's food security and is the backbone of livelihood for millions of rural households. It is a prince among the cereals and the premier staple food for many Asian, African, Latin American and Caribbean countries. At the global level, rice is grown in an area of about 163.2 million ha with production of 751.9 million tonnes and productivity of about 400–600 kg/ha (FAO, 2017). India ranks first in respect of area of 39.43 million ha and second in production of 107.04 million tonnes, only after China, but the rice productivity is very low, only 200–700 kg/ ha. In Uttar Pradesh it covers 5.29 million ha area with 11.94 million tonnes of production, but the productivity of rice is only 200 kg/ha (Anonymous, 2017). The demand for rice is increasing with growing population pressure, and its production has to be raised to 160 million tonnes by 2030 with a minimum annual growth rate of 2.35%. Basmati is of special importance among rice, since it is much remunerative than coarse rice due to vast scope of its export. The demand for basmati is much more in USA, European Union and Gulf countries but due to deteriorating quality, the export of Indian basmati to these countries is not increasing. Many factors are responsible for the deterioration of quality of produce; among them nutrient management is major. Therefore, it is important to cultivate basmati rice with the restricted use of chemicals so our produce may be competitive at the global market. As the land area is decreasing with time, increasing land use intensity with inadequate and imbalanced chemical fertilizers with little or no organic manure has caused severe fertility deterioration, stagnating or even declining crop productivity and quality (Thakur *et al.,* 2021). Integrated use of fertilizers, bio-fertilizers and farmyard manure seems to be the practicable alternative to the present malady of unsustainable agriculture. Farmyard manure is an easily available, cheap, proven source of nutrition to agricultural crops and has been used by the farmers traditionally. Besides supplying major and micronutrients, it also improves the physical, chemical and biological properties of soil. Use of farmyard manure supplies essential nutrients, improves soil health and enhances yield on sustained basis (Bana *et al.,* 2016). The conjoint use of organic manure and fertilizers is promising in maintaining

[1]**Corresponding author's Email:** shaktiomvns@gmail.com
[1]Assistant Professor, S.G.T. University, Gurugram, Haryana, 122 505; [2]Professor, Sardar Vallabh Bhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh 250110; [3]Assistant Professor, C.C.R. (PG), Muzaffarnagar, Uttar Pradesh, 251 001, [4]Associate Professor, Sardar Vallabh Bhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh 250 110, [5]Senior Research Fellow, ICAR-Indian Agricultural Research Institute, New Delhi 110 012

stability in crop production on certain soil through correction of the marginal deficiency of secondary and micronutrient elements in the course of mineralization of organic manure on the one hand and providing favorable physical, chemical, and soil ecological conditions (Sharma *et al.,*2020). There is no doubt about the role of organic sources on crop productivity and soil sustainability, but to establish a synchrony between the supply and demand of plant nutrients from organic sources, optimization of application timing is most important. Indian farmers are poor in resources and cannot afford chemical fertilizers due to escalating prices. However, it is imperative to use technologies in a conjoint manner so that the potential of rice could be realized on sustained basis. The objective of this study was to assess the effect of conjoint application of organic and chemical fertilizers on growth, yield and economics of basmati rice in western Uttar Pradesh.

MATERIALS AND METHODS

The present investigation was carried out during the *kharif* seasons of 2019 and 2020 at Crop Research Center, Sardar Vallabh Bhai Patel University of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh. The soil of the experimental field was sandy loam and neutral in reaction, low in organic carbon (0.47%) and available nitrogen (206.30 kg/ha), and medium in available phosphorus (12.40 kg/ha), potassium (137.00 kg/ha) and zinc (0.78 kg/ha). The experiment was laid out with 14 treatments of conjoint use of organic and chemical fertilizers viz. T_1, Control; T_2, RDF (120N : 60P : 50K); T_3, 25% recommended N through *dhaincha* incorporated 10 days before transplanting + rest N through chemical fertilizer (30 kg N SES 10 D + 75% RDN-F); T_4, 25% Recommended N through *dhaincha* incorporated 5 days before transplanting + rest N through chemical fertilizer (30 kg N SES 05 D + 75% RDN-F); T_5, 25% recommended N through *dhaincha* incorporated on planting date + rest of N through chemical fertilizer, 30 kg N SES P D+ 75% RDN-F; T_6, 25% recommended N through vermicompost incorporated 10 days before transplanting + rest N through chemical fertilizer, 30 kg N V 10 D + 75% RDN-F; T_7, 25% recommended N through vermicompost incorporated 5 days before transplanting + rest N through chemical fertilizer, 30 kg N V 05 D + 75% RDN-F; T_8, 25% recommended N through vermicompost incorporated on planting date + rest N through chemical fertilizer, 30 kg N V PD + 75% RDN-F; T_9, 37.5% recommended N through *dhaincha* incorporated 10 days before transplanting + rest N through chemical fertilizer, 45 kg N SES10 D + 62.5% RDN-F; T_{10}, 37.5% recommended N through *dhaincha* incorporated 5 days before transplanting + rest N through chemical fertilizer, 45 kg N SES 05 D + 62.5% RDN-F; T_{11}, 37.5% recommended N through *dhaincha* incorporated on planting date + rest N through chemical fertilizer, 45 kg N SES PD+ 62.5% RDN-F; T_{12}, 37.5% recommended N through vermicompost incorporated 10 days before transplanting + rest N through chemical fertilizer, 45 kg N V 10 D + 62.5% RDN-F; T_{13}, 37.5% recommended N through vermicompost incorporated 5 days before transplanting + rest N through chemical fertilizer, 45 kg N V 05 D+ 62.5% RDN-F and T_{14}, 37.5% recommended N through vermicompost incorporated on planting date + rest N through chemical fertilizer, 45 kg N V PD + 62.5% RDN-F in randomized block design with three replications. Rice seedlings 'Pusa Basmati 1509' with a plot geometry (20 cm × 10 cm) were transplanted on 15 July and 16 July 2019 and 2020, respectively. The recommended dose of fertilizer, *i.e.* P_2O_5 and K_2O were applied through DAP, SSP and MoP, and nitrogen was applied through urea and organic sources *dhaincha*, vermicompost. A full dose of phosphorus and potassium was applied at the time of transplanting, while 25 to 37.5 percent N through organic sources as per treatment and 12.5 to 25.0 percent through chemical fertilizer were applied before or at the time of transplanting. The remaining 50% nitrogen was applied in two equal splits at the maximum tillering and panicle initiation stage. The crop was raised with a recommended package of practices. During the crop-growing period, data with respect to different parameters of growth, yield attributes and yield of rice were collected. Leaf area index (LAI) was computed from the samples collected for dry matter estimation; leaves of 5 hills were plucked at tillering, panicle initiation and flowering and leaf area was measured using leaf area meter (LA-3100). The leaf area for each sample recorded was averaged to give the leaf area of plants/ hill. The following relationship was used to compute LAI (Watson, 1952) at each stage.

$$\mathrm{LAI} = \frac{\text{Leaf area (cm2)}}{\text{Land area (cm2)}}$$

The relative growth rate (RGR) is the rate of increase in dry weight per unit dry weight already existent, and it is measured in milligrams per gram of dry weight everyday (mg/g day) (Blackman, 1919).

$$\mathrm{RGR} = \frac{\text{Loge W2} - \text{LogeW1}}{\text{T2} - \text{T1}}\, gg - 1\, day - 1$$

Where W1 and W2 are the dry weight values at time T1 and T2, respectively. T1 and T2 are time in days.

The crop growth rate (CGR) is the rate at which dry matter is produced per unit of ground area per unit of time. CGR was determined using Watson (1952) formula and expressed in grams per square meter daily (g/ m^2 / day).

$$\mathrm{CGR} = \frac{\text{W2} - \text{W1}}{\text{T2} - \text{T1} \times \text{land area}}\, gday - 1m - 2$$

The economics of different treatments were calculated by using the following formulae.

Gross returns (₹/ha)= Monetary returns of seed yield (₹/ha) + Straw yield (₹/ha)

Net returns (₹/ha)= Gross return (₹/ha) – Total cost of cultivation (₹/ha)

Gross returns (₹/ha)

B: C ratio = $\frac{PV\ of\ the\ benefit\ expected}{PV\ of\ the\ cost}$

The data collected from different parameters were subjected to appropriate statistical analysis under a randomized complete block design by following the procedure of ANOVA analysis of variance (SAS Software packages, SAS EG 4.3). Significance of difference between means was tested through 'F' test and the least significant difference (LSD) was worked out where the variance ratio was found significant for the treatment effect. The treatment effects were tested at 5% probability level for their significance.

RESULT AND DISCUSSION

Growth parameters

There was significant variation in dry-matter accumulation under different treatments at almost all the growth stages during both years of experimentation. At 0–30 DAT, the maximum dry matter accumulation of 145.00 and 149.50 g/m^2 during 2019 and 2020, respectively, recorded with T_2 was significantly higher than T_1, T_8, T_9, T_{10}, T_{12}, T_{13}, T_{14} during 2019 and except for T_4, T_5, T_6, T_7 during 2020. At 30–60 DAT, the maximum dry-matter accumulation of 449.70 and 473.70 unit g/m^2 during 2019 and 2020, respectively recorded with T5 was significantly higher than T_1, T_3, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13} and T_{14} during 2019 and with exception of T_2, T_4, T_6 during 2020. At 60–90 days, the maximum dry matter accumulation of 701.30 and 715.70 g/m^2 during 2019 and 2020, respectively, found with the application of T_5 was significantly higher than the treatment except for T_2, T_4, T_6, T_7 during 2019 and 2020. The maximum dry matter accumulation 1,157.50 and 1,205.90 g/m^2 during 2019 and 2020 at harvest recorded in T5 was significantly higher than the treatments except for T_2, T_3, T_4, T_6, T_7 during 2019 and 2020. It might be due to the beneficial effect of *dhaincha* and vermicompost along with chemical fertilizers in improving the physical, chemical and biological environment of soil is conducive for better plant growth (Paul *et al*., 2014). This improvement in soil fertility might have favored the growth and development of rice crop in current study. The overall additive effect of *dhaincha*/vermicompost and chemical fertilizer additions on the improvement of soil properties might have resulted in significant improvement in the growth of crop plants.

Leaf area index (LAI)

Leaf-area is regarded to be optimum when photosynthesis is maximum. Below optimum LAI, the photosynthetic activity is less owing to sparse sunlight interception. At 0–30 days, the maximum leaf area index 2.24 and 2.46 during 2019 and 2020 respectively recorded in T_2 was *at par* with T_4, T_5, T_6, T_{11} and T_{12} during 2019 and T_5, T_6, T_{10}, T_{11}, T_{12} during 2020 while significantly higher than the rest of treatments (Table 1). At 30-60 days, the maximum leaf area index 4.98 and 4.94 during 2019 and 2020, respectively recorded with T_5 during both years was significantly higher than T_1, T_9, T_{13}, T_{14} and statistically *at par* with rest of the treatments.

At 60–90 days, the maximum leaf area index 4.12 and 4.18 during 2019 and 2020, respectively found with the application of T_5 was significantly higher than T_1 and T_{14} during both the years and statistically *at par* to the remaining treatments. Treatments consisting application of *dhaincha* or vermicompost to substitute 25 or 37.5% N did not differ significantly among themselves in respect of leaf-area index. Increase in LAI with the application of nutrients either in inorganic, organic or in their combinations is reported. This may be due to the fact that the presence of adequate N supply resulted in better utilization of carbohydrates to form more protoplasm. The cells produced under such conditions tend to be large with thin walls which may cause increase in leaf area (Black, 1967). Biomass production has shown an increasing trend with an increasing rate of NPS+Organic sources. The better performance under integrated nutrient application was closely associated with improved LAI and yield attributes (Birhanu, 2017).

Crop growth rate (CGR)

At 0–30 days, the maximum CGR 10.48 unit g/day/m^2 (T7) and 10.87 (T5) during 2019 and 2020, respectively was *at par* with T_2, T_4, T_5 and T_6 during 2019 and T_4 & T_6 during 2020 while significantly higher than the rest of treatments (Table 2). At 30–60 days, the maximum CGR 8.39 unit (T_5) and 8.40 (T7) during 2019 and 2020, respectively was *at par* with T_2, T_4 and T_6 during 2019 and T_2, T_3, T_4, T_5, T_6, T_8 and T_{12} during 2020 while significantly higher than the rest of treatments (Table 2). At 60–90 days, the maximum CGR 15.77 (T_4) and 16.58 (T_2) during 2019 and 2020, respectively was *at par* with T_2, T_3, T_5, T_7, T_8, T_{11} and T_{13} during 2019 and T_3, T_4, T_5, T_6, T_9, T_{10} and T_{11} during 2020 while significantly higher than the rest of treatments (Table 2).

Rice crop is a moderate feeder of nutrients required in available forms throughout the growing season. Growing of rice under combined application of both organic and inorganic sources of nutrients helped in supplying nutrients throughout the growing season that led to improved growth

Table 1. Effect of application timings of organic N sources on dry matter accumulation g/m^2 and LAI at different growth stages of rice on the basis of 2-years data

Treatment	Dry matter accumulation (g/m^2)								LAI					
	0–30 DAS		30–60 DAS		60–90 DAS		90–at harvesting		0–30 DAS		30–60 DAS		60–90 DAS	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T_1, Control	91.3	84.2	214.9	196.5	381.3	395.6	545.0	580.0	1.39	1.56	3.76	3.88	3.05	3.08
T_2, RDF (120N : 60 P : 50K)	145.0	149.5	449.3	447.6	678.3	690.0	1,137.5	1,187.5	2.24	2.46	4.82	4.64	3.98	4.06
T_3, 30 kg N SES 10 D + 75% RDN-F	131.3	124.6	394.3	393.1	607.5	637.1	1,048.3	1,111.9	2.00	1.94	4.63	4.54	3.80	3.84
T_4, 30 kg N SES 05 D + 75% RDN-F	135.0	137.7	440.1	449.2	671.7	688.9	1,144.9	1,171.7	2.06	2.10	4.56	4.76	3.96	3.84
T_5, 30 kg N SES P D+ 75% RDN-F	143.8	147.6	449.7	473.7	701.3	715.7	1,157.5	1,205.9	2.18	2.31	4.98	4.94	4.12	4.18
T_6, 30 kg N V 10 D + 75% RDN-F	144.0	141.8	448.0	446.5	691.7	693.3	1,110.0	1,176.7	2.19	2.32	4.91	4.82	4.02	4.10
T_7, 30 kg N V 05 D+ 75% RDN-F	132.3	138.2	446.7	429.8	658.7	681.9	1,094.6	1,130.0	1.98	2.18	4.60	4.78	3.76	3.98
T_8, 30 kg N V PD + 75% RDN-F	125.2	125.7	389.6	380.8	601.3	623.3	1,035.0	1,053.0	1.92	2.14	4.48	4.32	3.85	3.90
T_9, 45 kg N SES10 D + 62.5% RDN-F	122.5	116.4	375.2	357.9	588.8	585.0	976.7	1,050.0	1.90	2.10	4.46	4.32	3.86	3.90
T_{10}, 45 kg N SES 05 D+ 62.5% RDN-F	123.8	122.7	394.3	382.8	590.0	601.0	998.0	1,062.0	1.98	2.24	4.58	4.66	3.97	3.95
T_{11}, 45 kg N SESPD+ 62.5% RDN-F	131.3	127.5	399.0	394.2	600.0	613.0	1,025.0	1,080.0	2.20	2.36	4.84	4.74	4.08	4.02
T_{12}, 45 kg N V 10 D + 62.5% RDN-F	128.8	122.6	397.1	389.5	606.0	630.0	1,015.0	1,030.0	2.20	2.31	4.78	4.66	3.88	4.01
T_{13}, 45 kg N V 05 D+ 62.5% RDN-F	127.5	120.4	379.2	382.3	565.0	612.0	993.3	995.0	1.97	2.20	4.46	4.40	3.81	3.91
T_{14}, 45 kg N V PD + 62.5% RDN-F	126.3	116.0	370.5	365.7	540.0	590.0	958.9	975.0	1.86	2.18	4.31	4.38	3.66	3.68
SEm±	4.8	4.7	14.7	14.5	22.4	23.1	37.8	39.4	0.07	0.07	0.17	0.17	0.14	0.14
CD (P=0.05)	13.9	13.6	42.7	42.1	65.4	67.2	109.9	114.4	0.21	0.21	0.50	0.49	0.42	0.40

Table 2. Effect of application timings of organic N sources on crop growth rate and relative growth rate at different stages on the basis of 2-years data

Treatment	CGR (g/m^2/ day)						RGR (mg/g/day)					
	30–60 DAS		60–90 DAS		90–at harvesting		30–60 DAS		60–90 DAS		90–at harvesting	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T_1, Control	4.12	3.74	5.55	6.64	5.46	6.15	5.37	5.28	5.94	5.98	6.30	6.36
T_2, RDF (120N : 60 P : 50K)	10.14	9.94	7.63	8.08	15.31	16.58	6.11	6.10	6.52	6.54	7.04	7.08
T_3, 30 kg N SES 10 D + 75% RDN-F	8.77	8.95	7.11	8.13	14.69	15.83	5.98	5.97	6.41	6.45	6.95	7.01
T_4, 30 kg N SES 05 D + 75% RDN-F	10.17	10.38	7.72	7.99	15.77	16.09	6.09	6.11	6.51	6.54	7.04	7.07
T_5, 30 kg N SES P D+ 75% RDN-F	10.20	10.87	8.39	8.07	15.21	16.34	6.11	6.16	6.55	6.57	7.05	7.09
T_6, 30 kg N V 10 D + 75% RDN-F	10.13	10.16	8.12	8.23	13.94	16.11	6.10	6.10	6.54	6.54	7.01	7.07
T_7, 30 kg N V 05 D+ 75% RDN-F	10.48	9.72	7.07	8.40	14.53	14.94	6.10	6.06	6.49	6.52	6.99	7.03
T_8, 30 kg N V PD + 75% RDN-F	8.81	8.50	7.06	8.08	14.46	14.32	5.96	5.94	6.40	6.43	6.94	6.96
T_9, 45 kg N SES10 D + 62.5% RDN-F	8.42	8.05	7.12	7.57	12.93	15.50	5.93	5.88	6.38	6.37	6.88	6.95
T_{10}, 45 kg N SES 05 D+ 62.5% RDN-F	9.02	8.67	6.52	7.27	13.60	15.37	5.98	5.95	6.38	6.40	6.91	6.97
T_{11}, 45 kg N SESPD+ 62.5% RDN-F	8.92	8.89	6.70	7.29	14.17	15.57	5.99	5.97	6.40	6.42	6.93	6.98
T_{12}, 45 kg N V 10 D + 62.5% RDN-F	8.94	8.90	6.96	8.02	13.63	13.33	5.98	5.96	6.40	6.44	6.92	6.94
T_{13}, 45 kg N V 05 D+ 62.5% RDN-F	8.39	8.73	6.19	7.66	14.28	12.77	5.94	5.95	6.34	6.41	6.90	6.90
T_{14}, 45 kg N V PD + 62.5% RDN-F	8.14	8.32	5.65	7.48	13.96	12.83	5.92	5.90	6.29	6.37	6.87	6.88
SEm±	0.33	0.33	0.26	0.29	0.51	0.54	0.04	0.04	0.04	0.04	0.04	0.04
CD (P=0.05)	0.96	0.95	0.75	0.84	1.49	1.58	0.11	0.12	0.10	0.11	0.11	0.12

parameters of rice varieties (Choudhary and Suri, 2014).

Relative Growth Rate (RGR)

The RGR was computed at 3 different intervals, i.e. at 30–60 days, 60–90 days and 90– at harvest in both the years. The maximum RGR 6.108 g/g/day 6.160 (30–60 days), 6.552; 6.572 (60–90 days) and 7.053; 7.094 (90 days – at harvest) in the year 2019 and 2020 respectively was recorded in T_5 which was *at par* with T_2, T_4, T_6 and T_7 at 30-60 days, with T_2 and T_6 at 60–90 days and with T_2, T_4 and T_6 at 90- at harvest, while significantly higher than the rest of treatments (Table 2). The increase in RGR between 30–60 days and 60–90 days under different treatments varied from 109.31 to 158.98 per cent. Also, the increase in RGR between 60–90 days and 90– harvest under different treatments varied from 109.31 to 158.98%.

Although RGR reported under 25% recommended N through *dhaincha* incorporated on planting date + rest N through chemical fertilizer (T_5) treatment was at par with recommended dose of N P K (T_2) treatment. Yet, in the long-term considering soil fertility point of view, application of *dhaincha* or vermicompost would be more beneficial than chemical fertilizers alone.

Grain and straw yield

The grain yield varied significantly under different treatments, ranging from 1.97 to 4.15 and 1.97 to 4.01 t/ha during 2019 and 2020 respectively. Substitution of 25% N through *dhaincha* applied at the planting time or vermicompost applied 10 days before transplanting yielded non significantly higher than T_2, where 100% N was applied through chemical fertilizers during both years. The increment in yield was 7.7% with the application of *dhaincha* and 3.6% with vermicompost in 2019, while this increment was 4.8 and 1.4% in 2020. All the treatments of *dhaincha* except for T_9, during 2020 yielded statistically at par with T_2. Similarly, treatments consisting of substitution of 25% N through vermicompost incorporated at different timings also yielded at par with T_2, but this effect was not noticed with substitution of 37.5% N through vermicompost, where yield was significantly lower than T_2. Yield reduced drastically without fertilization during both years, and almost 52% of yield declined from the best treatment. Fertilization is an important technology in crop production, which could significantly improve the grain yield per unit area, and the combined application of organic and inorganic fertilizers is an effective cultivation measure to gain sustainable high rice yields (Wang *et al.,* 2021). It is clear from the table that the straw yields differ significantly under treatments from 3.42 to 6.92 and 3.49 to 6.70 t/ha during 2019 and 2020 respectively. Substitution of 25% N through *dhaincha* applied at the time of planting or

Table 3. Effect of application timing of organic N sources on Cost of cultivation, grossreturns, net returns and B:C ratio of basmati rice

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Cost of cultivation ₹/ha		Gross returns ₹/ha		Net returns ₹/ha		Benefit: cost ratio	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T_1, Control	1.97	1.97	3.82	3.89	31,507	31,507	42,578	45,852	11,071	14,345	1.4	1.5
T_2, RDF (120N : 60 P : 50K)	3.85	3.83	6.45	6.44	37,788	38,052	83,260	89,001	45,472	50,949	2.2	2.3
T_3, 30 kg N SES 10 D + 75% RDN-F	3.53	3.46	6.14	6.4.2	41,960	42,224	76,433	81,268	34,473	39,044	1.8	1.9
T_4, 30 kg N SES 05 D + 75% RDN-F	4.12	3.65	6.15	6.41	41,960	42,224	87,053	84,836	45,093	42,612	2.1	2.0
T_5, 30 kg N SES P D+ 75% RDN-F	4.15	3.88	6.85	6.64	41,960	42,224	89,076	90,005	47,116	47,781	2.1	2.1
T_6, 30 kg N V 10 D + 75% RDN-F	4.12	4.01	6.55	6.80	44,960	46,224	87,551	92,175	42,591	45,951	1.9	2.0
T_7, 30 kg N V 05 D+ 75% RDN-F	3.85	3.91	6.20	6.38	44,960	46,224	81,700	90,521	36,740	44,297	1.8	2.0
T_8, 30 kg N V PD + 75% RDN-F	3.84	3.62	6.10	5.99	44,960	46,224	81,554	83,680	36,594	37,456	1.8	1.8
T_9, 45 kg N SES10 D + 62.5% RDN-F	3.47	3.38	6.21	6.09	43,058	43,192	74,597	80,040	31,539	36,848	1.7	1.9
T_{10}, 45 kg N SES 05 D+ 62.5% RDN-F	3.75	3.48	5.67	5.99	43,058	43,192	79,384	80,863	36,326	37,671	1.8	1.9
T_{11}, 45 kg N SESPD+ 62.5% RDN-F	3.64	3.69	6.34	6.50	43,058	43,192	78,337	86,417	35,279	43,225	1.8	2.0
T_{12}, 45 kg N V 10 D + 62.5% RDN-F	3.40	3.13	5.93	6.06	47,558	49,192	73,229	73,072	25,671	23,880	1.5	1.5
T_{13}, 45 kg N V 05 D+ 62.5% RDN-F	3.12	3.07	5.98	5.84	47,558	49,192	68,364	73,845	20,806	24,653	1.4	1.5
T_{14}, 45 kg N V PD + 62.5% RDN-F	2.99	3.05	5.65	5.74	47,558	49,192	64,866	71,716	17,308	22,524	1.4	1.5
SEm±	0.24	0.13	0.33	0.29								
CD (P=0.05)	0.69	0.38	0.96	0.84								

vermicompost 10 days before planting yielded significantly higher than T_1, T_7, T_8, T_9, T_{10}, T_{12}, T_{13}, T_{14} in 2019, and T_1 in 2020 and *at par* to rest of the treatment during both the year. The increment in straw yield was 2.0% with the application of *dhaincha* and 1.0% with vermicompost in 2019, while this increment was 7.1 and 6.4% in 2020. The exception of T_1 and T_{14} during 2019, straw yield did not differ significantly among the other treatments, although straw yield declined slightly with the substitution of 37.5% N *dhaincha* and vermicompost in most cases. These results are supported by the report by Kumari *et al*. (2014).

Economics

The economic analysis of any experimental research is an important aspect for getting the most beneficial treatment combination from soil health and the farmer's point of view. A treatment with more chemical fertilizers may obtain the highest net returns with a minimum cost of cultivation compared to a treatment that includes organic sources but from soil health point of view. Its recommendation cannot make the maximum cost of cultivation is obtained under T_{12}, T_{13}, T_{14} (47558/ha) and (49192/ha), gross returns (89075/ha) and (92174/ha) net returns (47115/ha) and (50948/ha) minimum in control (T1), Highest gross returns found under T_5 in 2019 and T_6 in 2020, application of 25% N through *dhaincha* at planting date or vermicompost at 10 days before planting and net returns maximum found under T_2 in 2019 and T_5 in 2020. In 2020, T_2 and T_5 variation only Rs 3168/ha but T_5 is more beneficial from soil health point of view because it includes organic source *dhaincha,* which improve the physical, chemical and biological properties of soil. All the economic (Table 3) aspects like cost of cultivation, gross returns, net returns and benefit: cost ratio is maximum under T_2 (2.2) and (2.3), and the minimum is T_1 (1.4) and (1.5) during 2019–2020. Our results confirm the findings of Sharma *et al*., (2015) and Jat *et al*., (2021)

It can be inferred that the application of nitrogen through combination of *dhaincha*/vermicompost and chemical fertilizer will have a better response in terms of yield, growth and economics as compared to chemical fertilizers alone and may be recommended for the farmers of Uttar Pradesh and similar agro-Eco regions.

REFERENCES

Anonymous. 2017. Annual report 2017–18. *Department of Agriculture Cooperation and Farmers Welfare*, Government of India, p. 208.

Bana, R.S., Pooniya, V., Choudhary, A.K., Rana, K.S. and Tyagi, V.K. 2016. Influence of organic nutrient sources and moisture management on productivity, bio-fortification and soil health in pearlmillet (*Pennisetum glaucum*) + clusterbean (*Cyamopsis tetragonoloba*) intercropping system of semi-arid India. *Indian Journal of Agricultural Sciences* **86**(11): 1,418–1,425

Birhanu. 2017. Response of common bean (*Phaseolus vulgaris* L.) varieties to blended nitrogen, phosphorus and sulfur fertilizer rates at Areka, southern Ethiopia, Wolaita Sodo University, Ethiopia, M.Sc. Thesis.View at: Google Scholar.

Black, C.A. 1967. Soil Plant Relationship, 2nd Edn., 515—516. John Wiley & Sons Inc., New York.

Blackman, V. H. 1919. The compound interest law and plant growth. *Annals of Botany* **33**(131): 353–360.

Carriger, S., and Vallée, D. 2007. More crop per drop. *Rice Today* **6**(2): 10–13.

Choudhary, A.K. and Suri, V.K. 2014. Integrated nutrient management technology for direct-seeded upland rice (*Oryza sativa*) in northwestern Himalayas. *Communications in Soil Science and Plant Analysis* **45**(6): 777–784.

FAO. 2017. The treatment of agriculture in regional trade agreements. Trable policy briefs 29. FAO support to the WTO negotiations at the 11th Ministerial Conference in Buenos Aires. www.fao.org/3/a-i8010e.pdf.

Jat, M.L., Chaplot, P.C., Bairwa, D.D., Meena, S.N. and Dhayal B.C. 2021. Effects of integrated nutrient management on yield andeconomics of barley (*Hordeum vulgare*). *Indian Journal of Agronomy* **66**(4): 425–429.

Kumari, N., Pal, S.K., Barla, S. and Singh, C.S. 2014. Impact of organic nutrient management on dry matter partitioning, growth and productivity of scented rice. *Oryza* **51**(1): 48–54.

Paul, J., Choudhary, A.K., Suri, V.K., Sharma, A.K., Kumar, V. and Shobhna. 2014. Bioresource nutrient recycling and its relationship with bio fertility indicators of soil health and nutrient dynamics in rice-wheat cropping system. *Communications in Soil Science and Plant Analysis* **45**(7): 912–924.

Pooniya, V., Shivay, Y. S., Rana, A., Nain, L. and Prasanna, R. 2012. Enhancing soil nutrient dynamics and productivity of Basmati rice through residue incorporation and zinc fertilization. *European Journal of Agronomy* **41**: 28–37.

Sharma, G.D., Thakur, Risikesh, Chouhan, Narendra and Keram, K.S. 2015. Effect of Integrated nutrient management onyield, nutrient uptake, protein content, soil fertility and eco-nomic performance of rice (*Oryza sativa* L.) in a Vertisol. *Journal of Indian Society of Soil Science* **63**(3): 320–326.

Sherma, N., Shukla, Y.R. Singh, K. and Mehta, D.K. 2020. Soil fertility Nutrient Uptake and Yield & BELLPEPPER AS influenced by conjoint applicational organic and inorganic fertilizers. Communications in Soil Science and Plant Analysis, **51**(12): 1626–1640.

Thakur, Risikesh, Shrivastava, A.K., Sarvade, S., Rai, S.K., Koutu, G.K., Bisen, N.K. and Khan, M.I. 2021. Response of integrated application of inorganic fertilizersand vermicompost on rice productivity at farmer field. *International Journal of Plant and Soil Science* **33**(4): 25–31.

Watson, D.J. 1952. The physiological basis of variation in yield. *Advances in Agronomy* (4): 101–145.

Wang, F., Li, Q., He, C., Liu, C., You, Y.; Huang, Y. 2021. Combined return of rice straw and organic fertilizer to yellow-mud paddy soil to improve the rice productivity and substitute chemical fertilizers. *Chinese Journal of Eco-Agriculture* **29**: 2,024–2,033.

Indian Journal of Agronomy **68** (4): 357–362 (December 2023)

Research Paper

Potential organic nutrient management practices for wheat (*Triticum aestivum*) in south-eastern Rajasthan

B.S. MEENA[1], GAJENDRA NAGAR[2], SUSHEELA KALWANIYA[3] AND R.K. YADAV[4]

Agricultural Research Station, Ummedganj, Agriculture University, Kota, Rajasthan 324 001

Received: December 2022; Revised accepted: November 2023

ABSTRACT

A field experiment was conducted during winter (*rabi*) seasons of 2017–18 to 2021–22 at Agricultural Research Station, Ummedganj, Agriculture University, Kota, Rajasthan to develop natural and organic nutrient management technologies for sustainable wheat (*Triticum aestivum* L.) production to improve soil health and income security of the farmers. The experiment comprised of 8 treatments, viz. 100% N-FYM *fb* 10% cow urine (CU) spray at 25, 50 and 75 DAS; 50% N-FYM + 50% N-Vermicompost (VC) *fb* 10% vermiwash (VW) spray at 25, 50 and 75 DAS; 100% N-FYM + NPK consortia @1250 ml/ha as a soil application; 75% N-FYM + NPK consortia @1250 ml/ha as a soil application; 75% N-FYM + NPK consortia @1250 ml/ha as a soil application *fb* 10% cow urine spray at 25, 50 and 75 DAS; 75% N-FYM + NPK consortia @1250 ml/ha as a soil application *fb* amritasanjeevani spray @10% at 25, 50 and 75 DAS; jeevamrut @500 litre/ha at sowing, 25 and 50 DAS; and ghanjeevamrut @500 kg/ha at sowing, 25 and 50 DAS, in a randomized block design (RBD), replicated thrice. A critical examination of 5 years results revealed that significantly higher plant height (66.01 cm), tillers/plant (8.57), dry weight /meter row length (77.20 g), effective tillers/meter row length (80.60), ear length (8.93 cm), seeds/ear (44.90), test weight (41.90 g), seed yield (3756 kg/ha) and gross returns (₹100,605/ha) of wheat were obtained under the application of 50% N-FYM + 50% N-VC *fb*10% vermiwash spray at 25, 50 and 75 DAS over ghanjeevamrut @500 kg/ha at sowing, 25 and 50 DAS and jeevamrut @500 litre/ha at sowing, 25 and 50 DAS and on par with rest of treatments in pooled analysis. However, net returns (₹63,020/ha) and B:C ratio (1.77) of wheat were obtained significantly higher under application of 75% N-FYM+ NPK consortia @1,250 ml/ha as a soil *fb* amritasanjeevani spray @10% at 25, 50 and 75 DAS. Result on soil health improvement revealed that significantly higher organic carbon (0.66%), available phosphorus, potassium, sulphur (63.94, 432.8 and 28.21 kg/ha, respectively) and available zinc (0.90 mg/kg) were recorded with the application of 50% N-FYM + 50% N-VC *fb*10% vermiwash spray at 25, 50 and 75 DAS.

Key words: Amritasanjeevani, Beejamrut, Ghanjeevamrut, Jeevamrut, Vermicompost

Wheat (*Triticum aestivum* L.) is a native of south west Asia and stood one of the most important staple food crops that has been labelled as King of Cereals". Wheat is the world's leading cereal crop cultivated over an area of 221.11 million ha with a production of 785.10 million tonnes. In india, wheat is cultivated in almost all parts of the country, occupied 34.30 million ha with the production of 110.60 million tonnes and an average productivity of 3552 kg/ha. The major wheat producing states are Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, Rajasthan and Bihar which occupies 9.59, 7.15, 3.50, 2.36, 2.96 and 2.20 million ha area with the production of 33.94, 22.41, 14.82, 10.44, 9.48 and 6.22 million tonnes in the country, respectively (Anonymous, 2022–23).

[1]**Corresponding author's Email:** bhawanidamria@gmail.com
[1,3,4]Agricultural Research Station, Ummedganj, Kota, Rajasthan; [2]College of Agriculture, Ummedganj, Kota, Agriculture University, Kota, Rajasthan 324 001

Organic farming is a holistic production management system that sustains the health of soils, ecosystems and people which provides long-term benefits to people and environment (Hans, 2014). It is a unique production management system which promotes and enhances agro-ecosystem health including biodiversity, biological cycles and soil biological activity. Organic farming relies as much as possible on crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives and biological system of nutrient mobilization and plant protection (Raahinipriya and Rani, 2018). Farmyard manure (FYM) being a major source of all essential elements improves soil organic matter and humus part of the soil. It also plays an important role in inhabitation of beneficial bacterium thus making the nutrients available to crop (Raghuwanshi *et al*., 2016). Vermicompost is the microbial composting of organic wastes through earthworms' activity to form organic fertilizer which contains higher level of organic matter, organic carbon, total and available N, P, K and micronutrients, microbial and enzyme activities (Pandey *et al*., 2017; Verma *et al*., 2017). It increased the availability of nutrients, considerably resulting in a positive effect on growth parameters such as increased plant height, number of tillers/plant and number effective tillers per plant in wheat.

Supply of sufficient nutrient through organic sources in organic farming is the major issue responsible for low yield in conversion period. Combining more than one organic source for supplying nutrients to wheat has been found to be very effective instead of meeting the nutrient requirement by single source. Under the present situation, balanced nutrients supply by application of different organic formulations (Solid and liquid organic manures and NPK liquid consortia) with the important agronomic practices for enhancing wheat yield without deterioration soil fertility is the best option. Hence, an attempt has been made in the present study to find out the response of different organic formulations in combination with solid and liquid organic manures with the objective to improve wheat productivity and soil health in south- eastern Rajasthan.

MATERIALS AND METHODS

A field experiment was conducted during the *rabi* seasons of 2017–18 to 2021–22 at Agricultural Research Station, Ummedganj, Kota at fixed site in organic block under Maharshi Parashar Krishi Shodh Peeth to study the agronomic response of wheat under different organic nutrient formulations in south-eastern Rajasthan. The experiment was laid out in randomized block design with 3 replications and 8 treatments, viz. 100% N-FYM *fb* 10% cow urine (CU) spray at 25, 50 and 75 DAS; 50% N-FYM + 50% N-Vermicompost (VC) *fb* 10% vermiwash (VW) spray at 25, 50 and 75 DAS; 100% N-FYM + NPK consortia @1250 ml/ha as a soil application; 75% N-FYM + NPK consortia @1250 ml/ha as a soil application; 75% N-FYM + NPK consortia @1250 ml/ha as a soil application *fb* 10% cow urine spray at 25, 50 and 75 DAS; 75% N-FYM + NPK consortia @1250 ml/ha as a soil application *fb* amritasanjeevani spray @10% at 25, 50 and 75 DAS; jeevamrut @500 litre/ha at sowing, 25 and 50 DAS and ghanjeevamrut @500 kg/ha at sowing, 25 and 50 DAS, in a randomized block design (RBD). The experimental soil was clay loam in texture with a *p*H of 8.0, medium in organic carbon (0.55%), available nitrogen (362 kg/ha), phosphorus (55.5 kg/ha) sulphur (18.55 kg/ha), normal in zinc (0.68 mg/kg soil) and high in available potassium (417 kg/ha). Initial and post-harvest soil samples during 5 years were collected from 0–15 cm depth, dried processed and analysed for oxidizable organic carbon, N, P, K, S and Zn using standard procedures. The FYM (0.52% N, 0.24% P and 0.49% K) and vermicompost (1.5% N, 0.8% P and 1.0% K) were incorporated into the soil before sowing as per the treatments. A seed rate of 100 kg/ha of variety 'Raj 4037' was used during all the study years. Wheat was sown as *rabi* season crop in the second week of November in all years and harvested after attaining maturity. NPK liquid consortia (IFFCO made) was mixed with organic manures and applied as soil application at sowing time. The liquid organic manure was sprayed on standing crop at different growth stages. All the solid and liquid organic manures were applied as per treatments which were calculated on the basis of recommended dose of 120 kg/ha nitrogen equivalency in bulky organic manures. Wheat seeds were treated uniformly by beejamrut @50 ml/kg seed for 15–30 minutes in all treatments. All the agronomic and organic biopesticide plant-protections techniques were carried out uniformly as and when required. Yield attributes and yield of wheat were workout as per standard procedures, whereas economics was worked out on the basis of decided sell price at the centre.

Amritasanjeevani was prepared with the use of 5 components (fresh cow dung 60 kg, urea 3 kg, SSP 3 kg, potah 1 kg and groundnut cake 2 kg) firstly, kept urea, single super phosphate (SSP) and potash in a wide mounted plastic durm with 300 litre capacity and added water and closed the lid of drum for a period of 48 hours. Then after added remaining cow dung and ground nut cake, leave for next 4 days for fermentation. At the time of use, fill the drum completely with water. Sieved solution of amritasanjeevani @10% (50 litre/ha) was sprayed on standing crops. Jeevamrut was prepared with the mixture of 5 components (fresh cow dung 10 kg, 10 litre cow urine, 2 kg jaggery, 2 kg chickpea flour and 1 kg living soil, subsequently added in 200 liter water. All the items added to a wide mouthed plastic tank having a capacity of 300 liters. The container was kept under shade. This mixture was stirred twice a day in clock wise direction both in morning and evening. The jeevamrut stock solution was ready after 7 days. This solution was applied @500 liter/ha at a time with irrigation water. Ghanjeevamrut was prepared with a mixture of 5 components (200 kg fresh cow dung, 10 litre cow urine, 1 kg jaggery, 2 kg chickpea flour and 1 kg living soil (soil below baniyan tree). All the items mixed well and mixed material was kept under shade for 7 days, then after prepared materials was crushed/bating by stick/stone in fine particles before use in field. The ghanjeevamrut was ready for use after 7 days and kept in the shade. The rate of application was 500 kg/ha at each application on soil when it is wetted as per treatment. Vermiwash is a liquid extract obtained from vermicomposting process and used as an organic fertilizer for crop plant as 10% spray volume. To keep the moisture level in cow dung, water was sprayed drop by drop on the vermicompost heap or plastic tank. The moist organic waste was consumed and digested by the earthworms. The vermiwash produced during the vermicomposting process is an extract of both the earthworms' bodily fluids and the biomass they worked on. It is drained from the vermi-bed or heap and continues to be enriched with nutrients. This yellowish liquid released by the earthworms is known as vermiwash. Beejamrut was made from a mixture of 6 ingredients in the ratio 10:5:5:0.5:0.1:0.025, including water, cow dung, cow urine, milk, lime, and living soil, respectively (for treat 100 kg seeds) and it was fermented for 12 hours before treating the wheat seeds uniformly at the rate of 50 ml/kg for 15–30 minutes. All the data during individual years as well as in pooled analysis were statically analyzed by adopting appropriate method standard analysis of variance.

RESULTS AND DISCUSSION

Growth attributes

A critical examination of data revealed that application of different organic nutrient management practices significantly enhanced growth parameters at 60 DAS (Table 1). Data referred that organic nutrient management practice significantly influenced plant height, tillers/plant and dry weight g/mrl over the application of ghanjeevamrut. Further pooled data inferred that significantly higher plant height (66.01 cm), tillers/plant (8.57) and dry weight g/mrl (77.20) of wheat were recorded with the application of 50% N-FYM + 50% N-VC *fb* 10% vermiwash spray at 25, 50 and 75 DAS over ghanjeevamrut @500 kg/ha at sowing, 25 and 50 DAS and jeevamrut @500 litre/ha at sowing, 25 and 50 DAS which was found on par with 75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* amritasanjeevani spray 10% at 25,50 and 75 DAS; 100% N-FYM *fb* 10% CU spray at 25, 50 and 75 DAS; 100% N-FYM + NPK consortia @1250 ml/ha as soil and 75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* 10% CU spray at 25, 50 and 75 DAS. Increments in growth values might be owing to the increased availability of all essential nutrients due to application of organic manures such as farmyard manure, vermicompost along with three sprays of vermiwash (Ranva *et al*., 2022), which improves water holding capacity and increases macro and micro elements availability in the rhizosphere around roots system which in turns increased plant growth (Radwan *et al*., 2021).

Additionally, the significantly increased number of tillers/plants might have been due to the ready availability of nutrients like nitrogen, phosphorus, through liquid organic formulations, i.e. vermiwash as foliar spray at critical stages, which would have triggered tillers/plant. Similar findings were reported by Meena *et al*., (2021). The increased supply of optimum nutrition involving combination of all nutrients improved the growth parameters resulted in enhanced photosynthetic process led to higher interception and absorption of radiant energy, resulting into greater photosynthesis and finally increase dry matter accumulation. In fact, leaf is the factory for conversion of solar energy into chemical energy by the process of photosynthesis due to their increased amount of dry matter production. Our results are supported by the findings of

Table 1. Effect of organic nutrient management practices on growth and yield attributes of wheat (pooled data of 5 years)

Treatment	Growth attributes at 60 DAS			Yield attributes			
	Plant height (cm)	Tillers/ plant	Dry weight g/mrl	Effective tillers/mrl	Ear length (cm)	Seeds/ ear	Test weight (g)
100% N-FYM *fb* 10% CU spray at 25, 50 and 75 DAS	64.44	7.66	73.43	78.43	8.80	43.56	41.23
50% N-FYM + 50% N-VC *fb* 10% Vermiwash spray at 25, 50 and 75 DAS	66.01	8.57	77.20	80.60	8.93	44.90	41.90
100% N-FYM + NPK consortia @1250 ml/ha as soil	61.81	7.54	71.60	76.26	8.70	42.90	40.90
75% N-FYM + NPK consortia @1250 ml/ha as soil	58.31	7.02	67.93	72.26	7.93	38.90	38.90
75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* 10% CU spray at 25, 50 and 75 DAS	60.47	7.13	69.26	74.60	8.33	41.90	40.56
75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* amritasanjeevani spray 10% at 25, 50 and 75 DAS	65.34	7.91	74.66	79.26	8.86	44.23	41.56
Jeevamrut @500 litre/ha at sowing, 25 and 50 DAS	58.04	6.79	65.26	69.26	7.66	38.90	37.56
Ghanjeevamrut @500 kg/ha at sowing, 25 and 50 DAS	53.11	6.24	62.76	66.26	7.50	36.56	36.90
SEm±	2.15	0.34	2.36	2.19	0.27	1.55	0.86
CD (P=0.05)	6.52	1.04	7.14	6.63	0.81	4.68	2.60

N-FYM, nitrogen-farmyard manure; CU, cow urine; VC, vermicompost; fb, followed by; DAS, days after sowing.

Choudhary *et al*., (2017), Radwan *et al*., (2021) and Kumawat *et al*., (2022).

Yield attributes

Results (Table 1) revealed that application of different organic manures along with liquid formulations significantly influenced the yield attributes of wheat. Pooled data inferred that significantly higher effective tillers/mrl (80.60), ear length (8.93 cm), seeds/ear (44.90) and test weight (41.90 g) were obtained with the application of 50% N-FYM + 50% N-VC *fb* 10% vermiwash spray at 25, 50 and 75 DAS over ghanjeevamrut @500 kg/ha at sowing, 25 and 50 DAS and jeevamrut @500 litre/ha at sowing, 25 and 50 DAS which was found statistically on par with the application of 75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* amritasanjeevani spray 10% at 25, 50 and 75 DAS; 100% N-FYM *fb* 10% CU spray at 25, 50 and 75 DAS; and 100% N-FYM + NPK consortia @1250 ml/ha as soil and 75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* 10% CU spray at 25, 50 and 75 DAS. Moreover, liquid organic manure in combination with solid organic manures showed additive effect on yield attributes, this might be due to stimulatory effect of liquid organic manure on many physiological processes, such as respiration activities, cell division and many enzymes' activities. It also plays an important role in the regulation of photosynthetic carbon reduction. Yield of the wheat crop is a function of several yield components which are dependent on complementary interaction between vegetative and reproductive growth of the crop. As most of these growth and yield attributes showed significantly positive correlation with grain yield of wheat evidently resulted in higher yield in treatments (50% FYM + 50% VC *fb* VW spray 10%) which got timely nitrogen, appears to be on account of their influence on dry matter production and indirectly via increase in plant height, number of total tillers, number of effective tillers and possibly as a result of higher uptake of nutrients (Sen *et al*., 2011; Mathukia *et al*., 2014).

Yield

Results revealed that application of different organic nutrient sources significantly influenced the grain yield of wheat (Table 2). Significantly higher grain yield (3756 kg/ha) obtained with application of 50% N-FYM + 50% N-VC *fb* 10% vermiwash spray at 25, 50 and 75 DAS over application of ghanjeevamrut @500 kg/ha and jeevamrut @500 litre/ha at sowing, 25 and 50 DAS and found statistically on par with the application of 75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* amritasanjeevani spray 10% at at 25, 50 and 75 DAS; 100% N-FYM *fb* 10% CU spray at 25, 50 and 75 DAS, 100% N-FYM + NPK consortia @1250 ml/ha as soil; 75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* 10% CU spray at 25, 50 and 75 DAS; and 75% N-FYM + NPK consortia @1250 ml/ha as

Table 2. Effcet of organic nutrient management practices on yield, economics and soil available nutrients after harvest of wheat (pooled data of 5 years)

Treatment	Grain yield (kg/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	OC (%)	Available nutrients (kg/ha)			
						P_2O_5	K_2O	S	Zn (mg/kg)
100% N-FYM *fb* 10% CU spray at 25, 50 and 75 DAS	3511	92573	55523	1.49	0.64	61.91	429.4	25.81	0.83
50% N-FYM + 50% N-VC *fb* 10% Vermiwash spray at 25, 50 and 75 DAS	3756	100605	60352	1.50	0.66	63.94	432.8	28.21	0.90
100% N-FYM + NPK consortia @1250 ml/ha as soil	3412	91393	54568	1.48	0.63	60.55	427.0	25.11	0.82
75% N-FYM + NPK consortia @1250 ml/ha as soil	3332	89425	55000	1.59	0.61	60.41	425.5	24.01	0.80
75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* 10% CU spray at 25, 50 and 75 DAS	3398	91029	55854	1.64	0.62	60.75	426.4	24.61	0.77
75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* amritasanjeevani spray 10% at 25, 50 and 75 DAS	3739	98522	63020	1.77	0.63	62.27	427.0	25.01	0.75
Jeevamrut @500 litre/ha at sowing, 25 and 50 DAS	2961	79297	49797	1.69	0.60	58.39	424.9	22.11	0.73
Ghanjeevamrut @500 kg/ha at sowing, 25 and 50 DAS	2892	77378	48478	1.58	0.61	58.98	425.9	23.11	0.75
SEm±	155	3716	3716	0.11	0.006	0.55	4.24	0.22	0.005
CD (P=0.05)	435	10455	10455	NS	0.016	1.56	NS	0.61	0.014

N-FYM, nitrogen-farmyard manure; CU, cow urine; VC, vermicompost; fb, followed by; DAS, days after sowing soil. The overall growth and development of crop is reflected in the development of yield contributing characters which affect the final yield of the crop as these parameters are positively correlated to seed yield. These results corroborate with the findings of Verma *et al.,* (2020); Ravisankar *et al*., (2021) and Ranva *et al*., (2022).

Economics

Economics of wheat under different organic sources is presented in the Table 2. Among the different organic nutrient management options, the significantly higher gross returns (₹100,605/ha) and net returns (₹60,352/ha) were obtained with application of 50% N-FYM + 50% N-VC *fb* 10% vermiwash spray at 25, 50 and 75 DAS over ghanjeevamrut @500 kg/ha and jeevamrut @500 litre/ha at sowing, 25 and 50 DAS which remained statistically on par with application 75% N-FYM + NPK consortia @1250 ml/ha as soil + amritasanjeevani spray 10% at 25, 50 and 75 DAS; 100% N-FYM *fb* 10% CU spray at 25, 50 and 75 DAS; 100% N-FYM + NPK consortia @1250 ml/ha as soil; and 75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* 10% CU spray at 25, 50 and 75 DAS. Whereas, significantly higher net returns (₹63020/ha) was obtained with application of 75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* amritasanjeevani spray 10% at 25,50 and 75 DAS, which was statistically on par with application of 50% N-FYM + 50% VC *fb* 10% vermiwash spray at 25, 50 and 75 DAS; 75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* 10% CU spray at 25,50 and 75 DAS; 100% N-FYM *fb* 10% CU spray at 25, 50 and 75 DAS; 75% N-FYM + NPK consortia @1250 ml/ha as soil; and 100% N-FYM + NPK consortia @1250 ml/ha as soil. While the highest B:C ratio (1.77) of wheat was recorded with the application of 75% N-FYM + NPK consortia @1250 ml/ha as soil *fb* amritasanjeevani spray 10% at 25, 50 and 75 DAS as compared to rest of treatments due to low cost of cultivation during pooled of entire crop season. The cost of integration of organic nutrient formulation was compensated with the higher yield of wheat. Similar results were also reported by Chauhan *et al*., (2020) and Parewa *et al*., (2021).

Available nutrient status in soil

The available nutrients status in soil at the end of 5 years crop cycle revealed a positive effect of different organic nutrient management practices over initial value of nutrients in soil. Results revealed a significantly higher organic carbon (0.66%), available phosphorus, potassium and sulphur (63.94, 432.8 and 28.21 kg/ha) and available zinc (0.90 mg/kg) with application of 50% N-FYM + 50% N-VC *fb* 10% vermiwash spray at 25, 50 and 75 DAS over rest of the treatments in pooled basis. Soil organic carbon (SOC) concentrations in soil were probably enhanced by continuous application of carbon (C) inputs from FYM and vermicompost, higher root biomass and stubbles, rhizodepositions etc., and also from more microbial population that hastened decomposing of root biomass leading to higher accumulation of carbon in humified carbon fractions of soil. Similar findings were reported by Gopinath *et al*., (2008) and Bairwa *et al*., (2021). The increased available P, K and S status may be ascribed due to mineralization of organic sources and solubilization by microbes from native source, which probably increased the availability of P, K and S in the soil. Presumably combine application of solid and liquid organic manure such as farmyard manure, vermicompost and vermiwash increased the micronutrient content by supplying complexing agents, which formed stable complexes with these micronutrients as reported by Verma *et al.,* (2020) Ravisankar *et al*., (2021) and Ranva *et al*., (2022).

Based on results of 5 years experimentation, it may be concluded that application of 50% N-FYM + 50% N-vermicompost *fb* 10% vermiwash spray at 25, 50 and 75 DAS obtained significantly higher grain yield (3756 kg/ha) and gross returns (₹100,605/ha) of wheat over application of ghanjeevamrut @500 kg/ha and jeevamrut @500 litre/ha at sowing, 25 and 50 DAS, remained statistically at par to the rest of the treatments. Significantly maximum net returns (₹63,020/ha) and highest B: C ratio (1.77) of wheat were obtained under the application of 75% N-FYM + NPK consortia @1,250 ml/ha as soil *fb* amritasanjeevani spray 10% at 25, 50 and 75 DAS due to low cost of cultivation and better yield. While superior B:C ratio (1.69) of wheat was recorded with the application of jeevamrut @ 500 litre/ha at sowing, 25 and 50 DAS as compared to the rest of treatments except this treatment due to low cost of cultivation. A positive effect on available nutrients status in soil were also observed under these practices.

REFERENCES

Anonymous. 2022–23. Agricultural Statistics at a Glance. The Directorate of Economics and Statistics of the Department of Agriculture and Cooperation.

Bairwa, J., Dwivedi, B.S., Rawat, A., Thakur, R.K. and Mahawar, N. 2021. Long-term effect of nutrient management on soil microbial properties and nitrogen fixation in a vertisol under soybean-wheat cropping sequence. *Journal of the Indian Society of Soil Science* **69**(2): 171–178.

Chauhan, N., Sankhyan, N.K., Sharma, R.P., Singh, J. and Gourav. 2020. Effect of long-term application of inorganic fertilizers, farm yard manure and lime on wheat (*Triticum aestivum* L.) productivity, quality and nutrient content in an acid alfisol. *Journal of Plant nutrition* **43**(17): 2,569–2,578.

Choudhary, R.R., Yadav, H.L., Choudhary, S.L., Prajapat A.L. and Choudhary, R. 2017. Effect of integrated nutrient management on growth of wheat (*Triticum aestivum*) cultivars.

International Journal Current Microbiology Applied Sciences **6**(8): 2,369–2,374.

Gopinath, K.A., Saha, S., Mina, B.L., Pande, H., Kundu, S. and Gupta, H.S. 2008. Influence of organic amendments on growth, yield and quality of wheat and on soil properties during transition to organic production. *Nutrient Cycling in Agro ecosystems* **82**(1): 51–60.

Hans, V.B. 2014. Climate change and Indian agriculture. *EPRA International Journal of Climate and Economic Resource Review* **2**: 62–67.

Kumawat, L., Jat, L., Kumar, A., Yadav, M., Ram, B. and Dudwal, B.L. 2022. Effect of organic nutrient sources on growth, yield attributes and yield of wheat under rice (*Oryza sativa* L.) wheat (*Triticum aestivum* L.) cropping system. *The Pharma Innovation Journal* **11**(2): 1,618–1,623.

Mathukia, R.K., Gajera, K.D. and Mathukia, P.R. 2014. Validation of leaf colour chart for realtime nitrogen management in wheat. *Journal of Dynamics in Agricultural Research* **1**(1): 1–4.

Meena, A.M., Karwal, M., Raghavendra, K.J. and Kumari, P. 2021. Vermiwash: A potential tool for sustainable organic farming. *Food and Scientific Reports* **2**(5): 43–45.

Pandey, A., Li, F., Askegaard M. and Olesen, J.E. 2017. Biological nitrogen fixation in three long-term organic and conventional arable crop rotation experiments in Denmark. *European Journal of Agronomy* **90**: 87–95.

Parewa, H.P., Yadav, J., Meena, V.S. and Rakshit, A. 2021. Effects of chemical fertilizer, FYM and bio-inoculants on nutrient content, uptake and quality of wheat (*Triticum aestivum* L.). *Bangladesh Journal of Botany* **50**(4): 1,109–1,117.

Raahinipriya, P. and Rani, R.J. 2018. Consumers' purchasing behaviour towards organic products in Karur district, Tamil Nadu. *International Journal of Farm Sciences* **8**(3): 96–98.

Radwan, T., Ewais, M. and Ahmed, M. 2021. The combined effect of mineral N, organic and bio-fertilizers on wheat productivity. *Fayoum Journal of Agricultural Research and Development* **35**(2): 220–244.

Raghuwanshi, P., Khaddar, V.K. and Bhanger, K.S. 2016. Changes in status of organic carbon, available nitrogen and bacterial population in soils with organic manures. *Annals of Plant and Soil Research* **18**(4): 366–369.

Ranva, S., Singh, Y.V., Jain, N., Bana, R.S., Bana, R.C., Aseri, G.K. and Elansary, H.O. 2022. Impact of safe rock minerals, mineral fertilizers, and manure on the quantity and quality of the wheat yield in the rice-wheat cropping system. *Plants* **11**(2): 183.

Ravisankar, N. Ansari, M.A., Panwar, A.S., Aulakh, C.S., Sharma, S.K., Uganthy, M. S., Suja, G. and Jaganathan D. 2021. Organic farming research in India: Potential technologies and way forward. *Indian Journal of Agronomy* **66** (5th IAC Special issue): 142–162.

Sen, A., Srivastava, V.K., Singh, M.K., Singh, R.K. and Kumar, S. 2011. Leaf colour chart *vis-a-vis* nitrogen management in different rice genotypes. *American Journal of Plant Sciences* **2**(2): 223–236.

Verma, H.P., Sharma, O.P., Kumar, R., Yadav, S.S., Shivran, A.C. and Balwan, 2017. Yield attributes and yield of wheat (*Triticum aestivum* L.) as influenced by irrigation scheduling and organic manures. *Chemical Science Review and Letters* **6** (23): 1,664–1,669.

Verma, H.P., Sharma, O.P., Sharma, Seema, Rajesh Kumar and Shivran, A.C. 2020. Effect of irrigation scheduling and organic manures on wheat (*Triticum aestivum*) yield and soil nutrient status. *Indian Journal of Agronomy* **65**(4): 427–431.

Indian Journal of Agronomy **68** (4): 363–367 (December 2023)

Research Paper

Comparative analysis of the growth, yield attributes and grain yield of *kharif* maize (*Zea mays*) under varying doses of biochar, fertility levels, and biofertilizer treatments

SAURABH KUMAR VERMA[1], SURESH KUMAR[2] AND ALOK KUMAR PANDEY[3]

Acharya Narendra Deva University of Agriculture and Technology, is a university located in Kumarganj, Ayodhya, Uttar Pradesh 224 229

Received: December 2022; Revised accepted: December 2023

ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2021 and 2022 at the research farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj Ayodhya, Uttar Pardesh, to evaluate the effect of graded doses of biochar and fertility levels with and without biofertilizer under partially reclaimed sodic soils on maize (*Zea mays* L.) performance. The experiment was laid out in randomized block design (RBD) which with 3 replications. Experiment comprised of 8 treatments, viz. T_1, Control; T_2, 100% RDF 100 : 60 : 40 N, P_2O_5 and K_2O; T_3, 50% RDF + 2.5 t/ha biochar; T_4, 50% RDF + 2.5 t/ha biochar + ZMB Biofertilizer; T_5, 50% RDF + 2.5 t/ha biochar + ZMB Biofertilizer + Zn; T_6, 100% RDF + 5 t/ha biochar; T_7, 100% RDF + 5 t/ha biochar + ZMB Biofertilizer; T_8, 100% RDF + 5 t/ha biochar + ZMB Biofertilizer + Zn. The study's comparative analysis revealed the positive effects of applying biochar, optimal fertility levels, and biofertilizers on the yield attributes and grain yield of *kharif* maize. Notably, treatment T8 showed significant improvements, with a 53% increase in cob length, 34% increase in cob girth, 83% increase in the number of grains per row, 138.4% increase in grain yield, and 134% increase in stover yield compared to the control treatment. These findings demonstrate the successful impact of application of 100% RDF + 5 t/ha biochar + ZMB Biofertilizer + Zn in enhancing various aspects of maize growth and yield, surpassing the outcomes achieved with the control treatment and may be recommended for achieving high-quality maize production in partially reclaimed sodic soils of eastern Uttar Pradesh and comparable agro-ecoregions.

Key words: Biochar, Fertility levels, Maize, Yield attributes, Yield

Maize (*Zea mays* L.) is the third most important cereal crop in India as well as in the world next to rice and wheat. Globally it is highly valued for its multifarious use as food, feed, fodder and raw material for large number of industrial products. In India, maize is cultivated around 9.47 million ha area, with 28.6 million tonnes production and 3,190 kg/ha productivity (DACNET, 2022). Among Indian states Madhya Pradesh and Karnataka has highest area under maize (15% each) followed by Maharashtra (10%), Rajasthan (9%), Uttar Pradesh (8%) and others. The productivity of maize in India is about 3.19 t/ha, which is slightly more than the half of world average (5.6 t/ha). Over the years, increasing food and industrial demand of maize causes heavy pressure on natural resources and conventional agriculture which leads to threats like declining factor productivity, quality of produce, deterioration in physico-chemical and biological properties of soil, biotic interferences, declining biodiversity, high energy requirements, reduced availability of protective foods, stagnating farm income and global climate change (Abriz and Torabian, 2018).

Sodicity is a major constraint to crop productivity in many parts of the world, and its management is crucial for sustainable agriculture. In an attempt to achieve higher yield, farmers have resorted to using higher than the recommended levels of chemical fertilizer under salt affected soils in many areas in India (Agegnehu *et al.,* 2017). In Eastern Uttar Pradesh, sodicity affects a large area of cropland, and partially reclaimed sodic soils are common. Sodicity can lead to reduced soil fertility, low water infiltration rates, and poor soil structure, which can all impact

Based on a part of Ph.D. Thesis of the first author submitted to Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh in 2022 (unpublished)

[1]**Corresponding author's Email:** thearuagro2232@gmail.com
[1]Ph.D. Scholar, [2]Associate Professor, [3]Assistant Professor, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh 224 229

crop yields. To address these issues and develop answers, scientists have suggested switching to a sustainable crop production system. Therefore, understanding the role management factor impacting maize productivity, profitability and soil health is crucial to address future global food and nutritional security towards achieving sustainable agricultural goals.

Biochar is a carbon-rich soil amendment that has gained much attention in recent years due to its potential to improve soil fertility, nutrient cycling and carbon sequestration. It is produced by heating organic material, such as wood or crop residues, in the absence of oxygen, resulting in a porous, carbon-rich material that can be added to soils to improve their physical and chemical properties (Yohanes *et al*., 2015). The recent studies have focused on the use of biochar to improve soil quality and performance for better plant growth and productivity because it provides attachment sites for microbial communities (Adekiya *et al*., 2020) and effectively enhance soil physico-chemical properties by regulating soil *p*H. Biofertilizers, on the other hand, are products containing living microorganisms that can improve plant growth and soil fertility. The use of biofertilizers can help reduce chemical fertilizer use, which can be costly and have negative environmental impacts. Several studies have investigated the effects of biochar and fertility levels on soil properties and crop production, but little is known about their combined effects on performance of maize on partially reclaimed sodic soils in eastern Uttar Pradesh.

Hence, it was hypothesized that study will contribute to the understanding of the effects of biochar and fertility levels on maize performance in partially reclaimed sodic soils and provide insights into their combined use for improving crop productivity in sodic soils. Keeping above facts in view the an experiment was to study the response of maize to graded doses of biochar and fertility levels with and without biofertilizer under partially reclaimed sodic soils of eastern Uttar Pradesh.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif)* seasons of 2021 and 2022 at the Research Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj Ayodhya (26° 542 North and 81° 82' Eand at an altitude of 113 metre above mean sea-level), Uttar Pardesh. The climate of the site is semi-arid with hot summer and cold winter. The average rainfall received during the cropping period (June-September) was 670.94 mm. August month was the hottest month of the year where the maximum temperature hovers around 26.10 to 32.89°C, while, December was the coldest month when the mean minimum temperature was as low as 8.5°C. Ground frost is commonly associated with the winter seasons. The mean annual rainfall was about 1,067 mm, of which nearly 88.91% was received during the monsoon period from July to September and the rest during the period between October and May. The mean daily U.S. Weather Bureau Class 'A' open pan evaporimeter value reaches as high as 12.9 mm in August and as low as 1.5 mm in December. The mean annual pan evaporation was about 2080 mm. Mean relative humidity attains the maximum value (67.73 to 80.6%) during the south-west monsoon period and the minimum (30 to 45%) during the summer months. The soil of experimental was clay loam in texture with bulk density (1.35 Mg/m^3), *p*H 8.92, EC (0.23 dS/m), high organic carbon (0.41%), low available N (200.40 kg/ha), medium available P (15.40 kg/ha) and high available K (246.31 kg/ha). The experiment was conducted in randomized block design (RBD) comprised of 8 treatments, viz. T_1, Control; T_2, 100% -RDF 100:60:40 N, P_2O_5 and K_2O; T_3, 50% RDF + 2.5 t/ha biochar; T_4, 50% RDF + 2.5 t/ha biochar + ZMB Biofertilizer; T_5, 50% RDF + 2.5 t/ha biochar + ZMB Biofertilizer + Zn; T_6, 100% RDF + 5 t/ha biochar; T_7, 100% RDF + 5 t/ha biochar + ZMB Biofertilizer; T_8, 100% RDF + 5 t/ha biochar + ZMB Biofertilizer + Zn, replicated thrice.

The nutrients were supplied through biochar (containing 5.3 g/kg N, 0.99 g/kg P and 3.48 g/kg K), urea, diammonium phosphate and muriate of potash respectively. The treatment wise full dose of P and K and half the dose of N were applied as basal at sowing and the remaining N was top-dressed at 35 days after sowing. Maize cultivar, DA-61-A was sown during second week of February at 45 cm × 20 cm crop geometry with a seed rate of 20–22 kg/ha and harvested in the second week of July. The crop was raised with the recommended package of practices. The observations were recorded on yield attributes and yield. The length and girth of 10 cobs were measured from the randomly selected tagged plants of each plot with the help of a thread and centimetre scale. Then the average was worked out and expressed as the length and girth of the cob in cm. Total number of grain row of 10 selected cobs was counted and averaged to get number of grain row/cob. Total number of grains of 10 selected was counted, divided by number of rows/cob and expressed as number of grains/rows. The 10 cobs taken from each plot were shelled separately and counted. The averaged values were reported as number of grains/cob. The grain and stover yield was computed from the harvest of the net plot area from the individual plots and the weight of produce was recorded in kg/plot and finally converted into t/ha by using the conversion factor. The weight of total harvested produce from net plot of each treatment was recorded after sun drying and expressed as biological yield in t/ha.

The data collected for different parameters were subjected to appropriate statistical analysis under randomized block design (RBD) by following the procedure of ANOVA analysis of variance (SAS Software packages, SAS EG 4.3). Significance of difference between means was tested through 'F' test and the least significant difference (LSD) was worked out where variance ratio was found significant for treatment effect. The treatment effects were tested at 5% probability level for their significance.

RESULTS AND DISCUSSION

Growth parameters

The results showed that maximum plant height (206.7 and 212 cm) and dry-matter accumulation (329 and 333 g/plant) at harvest were recorded under T_8 treatment which was statistically at par with T_7 and significantly higher than other treatments, during both the years of experimentation (Fig. 1). The increase in growth parameters may be owing to the availability of nutrients at various critical crop growth stages in optimal amount which might have increased the cell division and cell elongation that results in higher plant height and dry-matter accumulation. These results are in conformity with the findings of Abbas *et al*., (2020). Enhancement in growth and yield attributes leads to better photosynthetic partitioning and source-sink relationship, which gave higher plant and drymatter accumulation. The similar findings were also reported by Zhang *et al*., (2020).

Yield attributes

Across the study years graded doses of biochar and fertility levels had significant effect on yield attributes of maize except number of cobs/plant and number of grains row/cob (Table 1). The maximum number of cobs/plant (1.36 and 1.40) and number of grains row/cob (15.8 and 16) was noticed under T_8 treatment and minimum was recorded in T_1 treatment (1.10 and 1.12). Significant rise in cob length approximately 57% and 50% was found under T_8 treatment followed by T_7 and T_6. During the first year, treatment T_8 resulted the maximum cob girth (15.2 cm) which was statistically at par with T_6 and T_7 and significantly higher than the other treatments. While, during the second year significantly highest cob girth (16.8 cm) was recorded under T_8 followed by T_7. The maximum number of grains/row (33.6 and 35.4) was recorded under T_8 which was statistically at par with T_6, T_7, T_2 and significantly higher than other treatments during both the years of experimentation. The highest number of grains/cob was noticed under T_8 which was significantly higher than other treatments during the first year, while during the second year significant highest number of grains/cob was recorded under T_8 treatment followed by T_7. The higher values of yield attributes were due to the effect on root development, energy transformation and metabolic processes of plant and resulted in more translocation of photosynthates towards the sink development (Faloye *et al.,* 2019a). Increase in yield attributes and yield of maize due to conjoint applica-

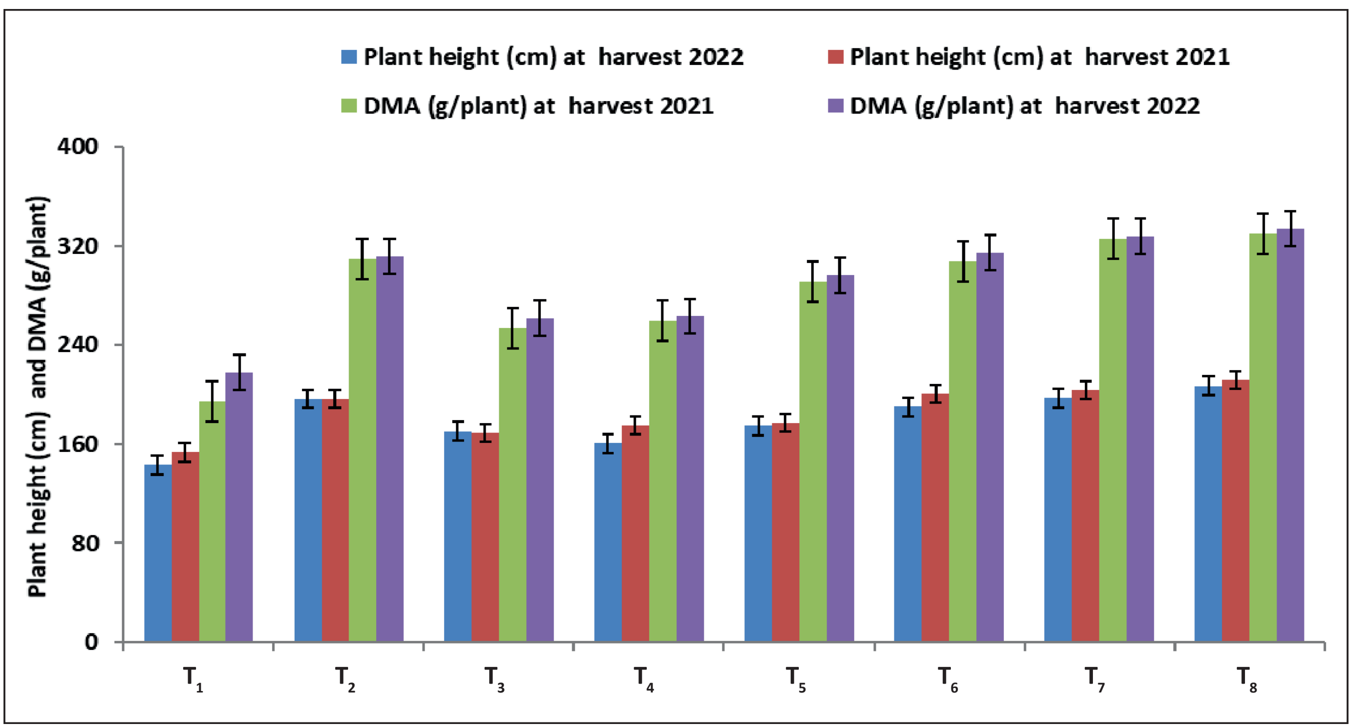

Fig. 1. Effect of graded doses of biochar and fertility levels with and without biofertilizer on growth parameters of maize crop
Treatment details are given under Materials and Methods. DMA, dry-matter accumulation.

Table 1. Effect of graded doses of biochar and fertility levels with and without biofertilizer on yield attributes of maize crop

Treatment	No. of cobs/plant		Cobs length (cm)		Cob girth (cm)		No. of grain rows/cob		No. of grains/row		No. of grains/cob		Grain yield (t/ha)		Stover yield (t/ha)		Biological yield (t/ha)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
T_1	1.10	1.11	12.6	13.3	11.7	11.9	12.3	12.9	18.6	19.1	230	246	2.42	2.52	3.66	3.81	6.09	6.18
T_2	1.17	1.15	16.3	16.7	14.2	15.5	15.2	15.5	31.3	32.5	475	505	5.08	5.10	7.56	7.62	12.6	12.6
T_3	1.14	1.12	16.1	16.4	13.6	13.8	13.6	14.0	24.9	27.7	341	388	4.63	4.72	6.91	7.02	11.5	11.7
T_4	1.07	1.09	15.7	16.5	13.8	14.0	13.8	13.8	27.8	30.4	386	420	4.74	4.76	6.86	7.12	11.6	11.8
T_5	1.09	1.11	16.0	16.8	14.1	15.3	14.6	14.7	29.9	31.8	437	468	4.87	4.88	7.19	7.41	12.0	12.2
T_6	1.16	1.17	19.3	19.8	14.4	15.7	15.0	14.8	30.8	33.2	464	494	5.23	5.25	7.78	7.82	13.0	13.0
T_7	1.18	1.18	19.5	19.7	14.6	16.1	15.2	15.5	32.2	34.1	492	529	5.47	5.51	7.86	8.28	13.3	13.7
T_8	1.20	1.21	19.8	20.0	15.2	16.8	15.8	16.0	33.6	35.4	534	567	5.77	5.82	8.35	8.48	14.1	14.3
SEm±	0.03	0.06	0.26	0.28	0.23	0.24	0.48	0.45	1.19	1.01	8.34	8.55	0.01	0.02	0.19	0.20	0.31	0.34
CD (P=0.05)	NS	NS	0.78	0.81	0.72	0.74	NS	NS	3.05	3.10	36.4	43.5	0.41	0.43	0.58	0.55	0.99	1.02

Treatment details are given under Materials and Methods.

tion of biochar and fertility levels support the development of strong root systems, which ultimately improves the plant growth and development and better diversion of photosynthates towards the sink. It also helps in the efficient absorption and utilization of the other required plant nutrients which ultimately increased the yield attributes (Razzaghi *et al*., 2020). The similar results and observations were also reported by (Faloye *et al.,* 2019b).

Yield (kg/ha)

Yield of maize was significantly influenced by graded doses of biochar and fertility levels during both the year of study (Table 1). Application of treatment T_8 resulted enhanced grain yield by 138.4% and 131% which was statistically at par with T_7 and significantly higher than remain treatments. During the first year significantly maxium stover yield was noticed under T_8 followed by T_7 and T_6 but during the second year higher stover yield was noticed under T_8 which was statistically at par with T_7 and significantly higher than reaming treatments. The treatment T_8 yielded maximum values of biological yield as compared to the other treatments but remained at par with T_7 during both the years of experimentation. It might be owing to the treatments with higher doses of biochar generally exhibited more significant improvements in yield attributes and yield compared to treatments with lower doses. Because it has a high surface area and a porous structure that can adsorb and retain nutrients, such as nitrogen, phosphorus, and potassium. This prevents nutrient leaching and increases the availability of essential nutrients to maize plants, promoting healthier growth and better yield attributes that results in more yield (Majid *et al*., 2017; Gudade *et al*., 2022). Application of biochar improve soil organic carbon, microbial biomass carbon, dehydrogenase activity, earthworm population and water availability, consequently results in good crop growth and productivity (Zheng *et al*., 2017; Ali *et al*., 2020).

Based on the findings of 2 years study it can be inferred that treatment T_8 exhibited remarkable improvements in various yield attributes and yield compared to the control treatment. Specifically, it showed a significant increase of 53% in cob length, 34% in cob girth, 83% in the number of grains/row, 138.4% in grain yield, and 134% in stover yield. These findings highlight the positive impact of treatment T_8 on the overall productivity and yield potential of the crop, indicating its effectiveness in enhancing maize growth and harvest outcomes when compared to the control group. Therefore, implementing a microbiota-driven integrated nutrient management strategy in conjunction with biochar and fertility levels is an energy-efficient and ecologically sustainable approach to ensure the production of high-quality maize in partially reclaimed sodic soils of eastern Uttar Pradesh and other similar agro-ecoregions.

REFERENCES

Abbas, A., Naveed, M., Azeem, M., Yaseen, M., Ullah, R., Alamri, S., Qurrat ul Ain Farooq and Siddiqui, M.H. 2020. Efficiency of wheat straw biochar in combination with compost and biogas slurry for enhancing nutritional status and productivity of soil and plant. *Plants* **9**: 15–16. doi: 10.3390/plants9111516

Abriz, S.F. and Torabian, S. 2018. Effect of biochar on growth and ion contents of bean plant under saline condition. *Environmental Science and Pollution Research* 1–9. https://doi.org/10.1007/s11356-018-1446-z

Adekiya, A.O., Agbede, T.M., Olayanju, A., Ejue, W.S., Adekanye, T.A., Adenusi, T.T. and Ayeni, J.F. 2020. Effect of biochar on soil properties, soil loss, and cocoyam yield on a tropical sandy loam alfisol. *Hindawi The Scientific World Journal* 9391630: 1–9.

Agegnehu, G., Srivastava, A.K. and Bird, M.I. 2017. The role of biochar and biochar-compost in improving soil quality and crop performance: A review. *Applied Soil Ecology* **119**: 156–170.

Ali, I., He, L., Ullah, S., Quan, Z., Wei, S., Iqbal, A., Munsif, F., Shah, T., Xuan, Y., Luo, Y., Li, T. and Ligeng, J. 2020. Biochar addition coupled with nitrogen fertilization impacts on soil quality, crop productivity, and nitrogen uptake under double-cropping system. *Food Energy Security* **9**: e208. doi: 10.1002/fes3.208

DACNET. 2022. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Govt of India. https://eands.dacnet.nic.in/PDF/Agricultural%20Statistics%20at%20a%20Glance%20-%202021%20(Hindi%20version).pdf

Faloye, O.T., Ajayi, A.E., Alatise, M.O., Ewulo, B.S. and Horn, R. 2019a. Nutrient uptake, maximum yield production, and economic return of maize under deficit irrigation with biochar and inorganic fertiliser amendments. *Biochar* **1**: 375–388. doi: 10.1007/s42773-019-00032-3

Faloye, O.T., Alatise, M.O., Ajayi, A.E. and Ewulo, B.S. 2019b. Effects of biochar and inorganic fertiliser applications on growth, yield and water use efficiency of maize under deficit irrigation. *Agricultural Water Management* **217**: 165–178. doi: 10.1016/j.agwat.2019.02.044

Gudade, B.A., Malik, G.C., Das, A., Babu, S., Banerjee, M., Kumar, A., Singh, R. and Bora, S.S. 2022. Performance of French bean crop as influenced by biochar levels and INM practices in acid Inceptisol of Meghalaya. *Annals of Agricultural Research* **43**(2): 84–89.

Majid M.A., Islam, M.S., EL-Sabagh, A., Hassan, M.K., Saddam, M.O., Barutcular, C.D. Ratnasekera, D. and Abdelaal, K.A. 2017. Influence of varying nitrogen levels on growth, yield and nitrogen use efficiency of hybrid maize (*Zea mays*). *Journal of Experimental Biology and Agricultural Sciences* **5**(2): 134–142.

Razzaghi, F., Obour, P. B. and Arthur, E. 2020. Does biochar improve soil water retention? A systematic review and meta-analysis. *Geoderma* **361**: 114055. doi: 10.1016/j.geoderma.2019.114055

Yohanes, P.S., Adnyana, I.M., Nengah, I., Subadiyasa, N. and Merit, I.N. 2015. Effect of dose biochar bamboo, compost, and phonska on growth of maize (*Zea mays* L.) in dryland. *International Journal Advanced Science Engineering Information and Technology* **5**(6): 433–439.

Zhang, X., Qu, J., Li, H., La, S., Tian, Y. and Gao, L. 2020. Biochar addition combined with daily fertigation improves overall soil quality and enhances water fertilizer productivity of cucumber in alkaline soils of a semi-arid region. *Geoderma* **363**: 114170. doi: 10.1016/j.geoderma.2019.114170

Zheng, J., Han, J., Liu, Z., Xia, W., Zhang, X. and Li, L. 2017. Biochar compound fertilizer increases nitrogen productivity and economic benefits but decreases carbon emission of maize production. *Agriculture Ecosystem and Environment* **241**: 70–78. doi: 10.1016/j.agee.2017.02.034

Indian Journal of Agronomy **68** (4): 368–372 (December 2023)

Research Paper

Evaluation of maize (*Zea mays*) genotypes under different nitrogen levels in a Trans-Gangetic Plains region

SHANTI DEVI BAMBORIYA[1], SHIVA DHAR[2], PRAVEEN KUMAR UPADHYAY[3], ANCHAL DASS[4], RAJENDRA PRASAD MEENA[5] AND KAMAL GARG[6]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Received: December 2022; Revised accepted: October 2023

ABSTRACT

An experiment was conducted during rainy (*kharif*) seasons of 2021 and 2022 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi to study the effects of different genotypes and nitrogen levels on growth and yield of maize (*Zea mays* L.). Six maize genotypes ('AH 4271', 'DKC 9164', 'PJMH 1', 'PMH 13', 'PC 4' and Pusa Vivek QPM 9' Improved (PV QPM 9-I) and 7 levels of nitrogen (0, 40, 80, 120, 160, 200 and 240 kg N/ ha) were evaluated using factorial randomized complete block design with two replications. Results showed that among the genotypes the 'DKC 9164' produced the highest kernel yield and resulted in maximum net returns (₹ 78.0 and 82.8 × 10^3/ha) as compared to other genotypes. The growth parameters and yield increased with the increasing level of nitrogen from 0 to 240 kg/ha. Application of nitrogen @240 kg N/ha produced the maximum plant height, total number of leaves, leaf area index and stover as well as biological yield, whereas the maximum kernel yield and net returns (₹ 91.1 & 97.2 × 10^3/ha) were obtained with 200 kg N/ha which was at par with 160 kg N/ha

Key words: Genotype, Growth parameters, Maize, Nitrogen, Yield

Maize (*Zea mays* L.) is one of the most important crops in the world, occupying third place after rice and wheat in terms of cereal crop production (FAO, 2018). In India it is grown on 9.86 million ha area, contributing 31.5 million tonnes produce (DES, 2021), and employing roughly 15 million farmers (Dhillon *et al.,* 2020). It is referred to as the 'queen of cereals' since it is the most widely produced, fastest-growing, short-duration crop with the highest potential yield (Begam *et al*., 2018). It is a traditional crop that is typically used for food, feed and fodder (Govind *et al*., 2015) and plays a major role in the human nutrition, animal industry, and biofuel production.

To achieve the maximum yield, genotypes suitable for specific agro-ecological conditions, seasons, uses, and crop period must be chosen because different varieties responded differently to their genotypic characteristics, input requirements, and growth process under the dominant environment. Maize being a high nutrient mining crop needs a higher amount of nitrogen for its economic production (Adhikary *et al*., 2020). The response of maize plants to the application of nitrogen fertilizers varies from variety to variety, location to location, and also depends on the availability of the nutrients (Onasanya *et al*., 2009). Local varieties of maize are less responsive to high rates of nitrogenous fertilizers than hybrid and improved maize varieties (Shrestha *et al*., 2018) which consume fertilizers in high rates.

Nitrogen is one of the most vital and costly inputs in the production of maize. Nitrogen application timings and its suitable rate are unquestionably linked to better nitrogen management (Khan and Akma, 2021). Only 33% of applied nitrogen is converted to grain production (Bryant-Schlobohm *et al.,* 2020); superfluous nitrogen (>60%) is lost from the plant-soil system in the form of surface run-off, volatilized ammonia or nitrogen oxide emissions, or it is leached beyond the root zone as nitrate, posing major environmental risks such as global warming, water and soil pollution, and climate change (Dhital and Raun, 2016). In agricultural crops, efficient nitrogen use is increasingly becoming more significant since it has the potential to lower fertilizer input and increase nitrogen use efficiency. The significance of nitrogen is fairly obvious, but efforts must be made to identify the ideal level of nitrogen for boosting yield while taking into account the cost and availability of nitrogen fertilizers. Therefore, a study was carried

[2]**Corresponding author's Email:** drsdmisra@gmail.com
[1]Scientist, ICAR-Indian Institute of Maize Research, New Delhi 110 012; [2,4]Principal Scientist, [3]Scientist, [5,6]Ph.D. Scholar, Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi 110 012

out to determine the optimal nitrogen application levels for various maize genotypes. For this purpose, genotypes with varying maturity, morphologies and yield potentials were chosen.

MATERIALS AND METHODS

An experiment was conducted during rainy (*kharif*) seasons of 2021 and 2022 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi (28° 4'N, 77° 12'E and at 228.6 m amsl) under irrigated condition. The test soil was sandy loam, slightly alkaline (7.7) and poor in organic carbon content (0.44%). It was also low in available N (185 kg/ha) and medium in available P (12.8 kg/ha) and K (205 kg/ha). The total rainfall received during crop growing period was 1256 and 821 mm, respectively during 2021 and 2022. The experiment was conducted in the factorial randomized block design (RBD) design and replicated twice. The experiment comprises of 6 maize genotypes, viz. 'AH 4271', 'DKC 9164', 'PJMH 1', 'PMH 13', 'PC 4' and 'Pusa Vivek QPM 9' Improved (PV QPM 9-I) and 7 levels of nitrogen, viz. 0, 40, 80, 120, 160, 200 and 240 kg N/ha. Nitrogen was applied in 3 equal splits at sowing, 30 and 45 days after sowing (DAS). A recommended amounts of P (80 kg P_2O_5/ha) and K (60 kg K_2O/ha) were applied by single super phosphate (SSP), and muriate of potash (mop), respectively as basal dose. Maize was planted on 15 July 2021 and 09 July 2022 at 5 cm depth with 60 cm rows spacing and 20 cm plant-to-plant spacing using 20 kg seeds/ha. Recommended package of practices were followed to raise the crop. All the observations were taken following the standard methodology.

RESULTS AND DISCUSSION

Growth parameters

Plant height: The result shows that plant height was significantly influenced by the genotype and nitrogen levels. During both the years, genotype 'PJHM 1' recorded the maximum plant height which was statistically at par to 'DKC 9164' (Table 1). Nitrogen dose 240 kg/ha had the maximum plant height whereas minimum height was recorded with control during both the years. An increase in chlorophyll content due to nitrogen application increased the rate of photosynthesis, therefore, the plant grew faster and taller (Adhikari *et al*., 2021).

Leaf count: The results further showed that the genotype and nitrogen levels had significant effect on total leaf number/plant. Among the genotypes the minimum leaf number/plant was recorded with genotype 'PV QPM 9-I '(10.0 and 11.0), whereas, maximum was found with genotype 'PJHM 1' (13.6 and 12.2) which was at par with 'DKC 9164' (Table 1). The plants applied with 240 N kg/ha recorded the highest number of total leaves whilst, the control plants applied with 0 N kg/ha recorded the lowest number of total leaves during both the years. This might be owing to the enhanced cell division and elongation under nitrogen fertilization which supported vegetative growth, stem elongation and leaf production etc.

Table 1. Effect of genotypes and nitrogen levels on plant height, leaf count and leaf area index of maize during 2021 and 2022

Treatment	Plant height (cm)		Total leaves/plant		Leaf area index at silking	
	2021	2022	2021	2022	2021	2022
Genotype						
'PJHM 1'	177.8	182.0	12.2	13.6	3.79	3.85
'PC 4'	156.4	160.3	11.5	12.6	3.77	3.83
'DKC 9164'	170.4	174.4	12.4	13.4	3.83	3.94
'PMH 13'	160.8	164.6	11.8	12.8	3.85	3.96
'AH 4271'	167.7	173.7	12.8	12.8	3.73	3.79
'PV QPM 9-I'	152.4	156.6	10.0	11.0	2.84	2.94
SEm±	3.7	4.0	0.3	0.2	0.08	0.04
CD (P=0.05)	10.7	11.4	0.8	0.6	0.24	0.13
Nitrogen level (N) (kg/ha)						
0	114.0	120.3	9.2	10.5	2.51	2.58
40	139.1	144.5	11.0	12.0	3.06	3.14
80	166.3	171.4	11.6	12.5	3.44	3.52
120	172.8	176.8	12.1	13.0	3.89	3.97
160	181.5	184.9	12.4	13.1	4.02	4.09
200	186.1	189.1	12.8	13.6	4.19	4.26
240	190.0	193.1	13.4	14.1	4.34	4.41
SEm±	4.0	4.3	0.3	0.2	0.09	0.05
CD (P=0.05)	11.5	12.3	0.9	0.7	0.26	0.14
Interaction (G × N)	NS	NS	NS	NS	NS	*

Leaf area index: The effect of different genotypes and nitrogen levels on leaf area index was highly significant (Table 1). Leaf area index of 'PMH 13' was significantly 1.35 times greater than 'PV QPM 9-I', which had the lowest leaf area. There was 1.72 times higher leaf area index was obtained with the application of 240 kg N/ha over the control. Similar results were also reported by Adhikari *et al*., (2021).

Yield and harvest index

Kernel yield: Maize kernel yield was significantly affected by genotype, nitrogen levels and their interaction (Fig. 1). The genotype 'DKC 9164' recorded the highest kernel yield, whilst genotype 'PV QPM 9-I' recorded the least yield during both the years. Hybrid DKC 9164 recorded the highest kernel yield because it exhibited a longer grain filling period. Kernel yield increased with nitrogen fertilizer up to a certain level and declined with excess nitrogen. 'PC 4' and 'PV QPM 9-I' positively responded up to 160 kg N/ha while rest of genotypes showed increased yield up to 200 kg N/ha. Nitrogen stress induces barrenness by delaying silking and reduces kernel/cob due to non-synchronous flowering (Bello *et al*., 2014), therefore yield reduction was observed at 0 kg N/ha. Decreased maize yield with excess nitrogen fertilizer application may be associated with reduced root growth and harvest index,

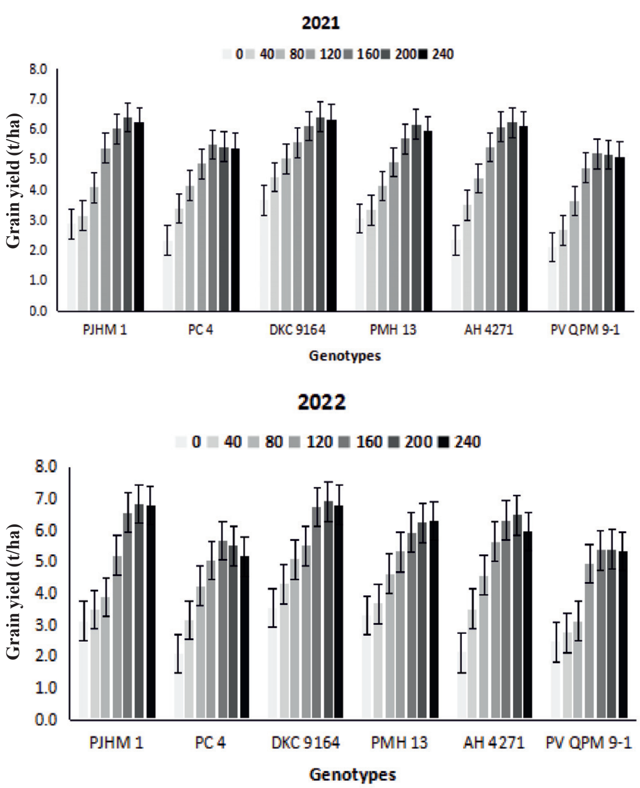

Fig. 1. Interaction effects of genotypes and nitrogen levels on kernel yield of maize during 2021 and 2022.

and higher pest infestation. Conservation agricultural practices such as crop residue retention could reduce N requirement of hybrid maize by 40 kg/ha without affecting the kernel yield (Sarangi *et al*., 2020).

Stover yield: Genotypes 'DKC 9164' produced higher stover yield than the other genotypes during both the years (Table 2). Genotypes 'DKC 9164' and 'PJHM 1' grew taller and had thicker stem with greater leaf production. The features stated led to greater stover yields in both the genotypes. Besides, 'DKC 9164' is a long duration hybrid therefore accumulated highest amount of biomass than rest other genotypes. Contrarily, 'PV QPM 9-I' had the least stover yield possibly due to its shorter maturity duration. Nitrogen level of 240 kg/ha had the highest stover yield whereas 0 kg N/ha recorded the lowest stover yield. This could be as a result of higher plant height, leaf number, stem diameter and leaf area index at 240 kg N/ha.

Biological yield: Amongst the genotypes, numerically higher values of biological yield was recorded with genotype 'DKC 9164', whilst the lowest was observed in 'PV QPM 9-I' (Table 2). Further results indicated that biological yield of maize also increased along with the level of nitrogen fertilizer. Generally, the superiority of biological yield based on nitrogen levels are as: 240>200>160>120>80>40>0 kg N/ha.

Harvest index: Different genotypes and nitrogen levels showed significant differences in harvest index (Table 2). 'AH 4271' had the greatest harvest index which indicates that the genotype partitioned greater amount of the photosynthate into grain over vegetative plant parts. 'PC 4' recorded the least value of harvest index which was due to its larger total biomass in comparison to kernel weight. Amanullah (2014) also reported lower harvest index with composite varieties over hybrid. Up to 200 kg N/ha nitrogen rate increased the harvest index and beyond that it decreased. Earlier, Amanullah (2014) also reported positive relationship between harvest index and nitrogen rates up to a certain level (150 kg N/ha).

Economics

The highest gross returns, net returns and benefit cost (B:C) ratio were recorded with 'DKC 9164' followed by 'PJHM 1', 'AH 4271', 'PMH 13' and 'PC 4' whereas the least economical profits were fetched from 'PV QPM 9-I' (Table 3). The higher gross and net returns from 'DKC 9164' is mainly attributed to higher kernel and straw yields. 'DKC 9164' had the highest cultivation costs, which were caused by its more expensive seed compared to genotypes from the public sector. Cost of cultivation increased with nitrogen levels and application of 240 kg N/ha incurred maximum production cost. Whereas, gross and net returns as well as B:C ratio were increased with nitrogen

Table 2. Effect of genotypes and nitrogen levels on stover and biological yields, and harvest index of maize during 2021 and 2022

Treatment	Yield (t/ha)				Harvest index (%)	
	Stover		Biological			
	2021	2022	2021	2022	2021	2022
Genotype						
'PJHM 1'	8.05	8.42	12.9	13.5	37.3	37.7
'PC 4'	7.61	7.54	12.0	11.9	36.8	36.3
'DKC 9164'	8.98	9.52	14.3	15.1	37.2	36.0
'PMH 13'	7.98	8.24	12.7	13.3	37.0	37.7
'AH 4271'	7.76	7.94	12.6	12.9	37.9	37.8
'PV QPM 9-I'	6.77	6.96	10.9	11.2	37.3	37.1
SEm±	0.18	0.20	0.2	0.3	0.2	0.1
CD (P=0.05)	0.52	0.57	0.7	0.8	0.6	0.3
Nitrogen level (N) (kg/ha)						
0	5.28	5.42	8.0	8.2	34.2	33.8
40	6.33	6.30	9.7	9.8	35.2	35.4
80	7.54	7.72	11.8	12.0	36.0	35.5
120	8.24	8.66	13.4	13.9	38.5	38.0
160	8.83	9.45	14.6	15.5	39.6	39.2
200	9.06	9.47	15.0	15.7	39.7	39.6
240	9.74	9.70	15.6	15.8	37.5	38.3
SEm±	0.20	0.22	0.3	0.3	0.2	0.3
CD (P=0.05)	0.56	0.62	0.8	0.9	0.6	0.9
Interaction (G × N)	NS	NS	NS	NS	*	*

Table 3. Effect of genotypes and nitrogen levels on economics of maize during 2021 and 2022

Treatment	Cost of cultivation ($\times 10^3$ /ha)		Gross returns ($\times 10^3$ /ha)		Net Returns ($\times 10^3$ /ha)		Benefit: cost	
	2021	2022	2021	2022	2021	2022	2021	2022
Genotype								
'PJHM 1'	35.7	36.7	106	112	70.6	75.6	1.95	2.04
'PC 4'	35.7	36.7	97	97	61.4	60.8	1.70	1.65
'DKC 9164'	39.1	40.1	117	123	78.0	82.8	1.98	2.06
'PMH 13'	35.7	36.7	104	111	67.9	74.2	1.88	2.01
'AH 4271'	35.7	36.7	106	108	69.7	71.6	1.93	1.94
'PV QPM 9-I'	35.7	36.7	89	92	53.3	55.6	1.47	1.50
SEm±	-	-	2	2	1.6	2.1	0.04	0.06
CD (P=0.05)	-	-	5	6	4.5	6.1	0.12	0.16
Nitrogen level (N) (kg/ha)								
0	34.0	35.0	61	63	26.4	27.0	0.75	0.76
40	34.8	35.8	76	78	40.3	41.2	1.13	1.13
80	35.2	36.2	93	95	57.4	58.0	1.59	1.58
120	35.7	36.7	112	116	75.2	78.3	2.07	2.10
160	36.2	37.2	124	133	87.4	95.1	2.37	2.52
200	36.6	37.6	129	135	91.1	97.2	2.44	2.55
240	37.1	38.1	128	133	89.8	93.9	2.37	2.43
SEm±	-	-	2	2	1.7	2.3	0.05	0.06
CD (P=0.05)	-	-	5	7	4.9	6.6	0.13	0.18

application up to 200 kg N/ha. Due to decrease in yield, excessive nitrogen fertilizer (240 kg N/ha) reduced the net return and B:C ratio.

After reviewing the aforementioned studies, it may be concluded that varietal performance may differ depending on its genetic make-up or the climatic conditions. For composite variety and short duration hybrid of maize (75–80 days), 160 kg N/ha was found most economical, while medium (90–95 days) and long duration (>95 days) hybrids of maize performed well at 200 kg N/ha.

REFERENCES

Adhikari, K., Bhandari, S., Aryal, K., Mahato, M. and Shrestha, J. 2021. Effect of different levels of nitrogen on growth and yield of hybrid maize (*Zea mays* L.) varieties. *Journal of Agriculture and Natural Resources* **4**(2): 48–62.

Adhikary, B.H., Baral, B.R. and Shrestha, J. 2020. Productivity of winter maize as affected by varieties and fertilizer levels. *International Journal of Applied Biology* **4**(1): 85–93.

Amanullah. 2014. Source and rate of nitrogen application influence agronomic N-use efficiency and harvest index in maize (*Zea mays* L) genotypes. *Maydica* **59**: 80–89.

Begam, A., Ray, M., Roy, D.C. and Sujit, A. 2018. Performance of hybrid maize (*Zea mays* L.) in different levels and time of nitrogen application in Indo-Gangetic plains of eastern India. *Journal of Experimental Biology and Agricultural Sciences* **6**(6): 929–935.

Bello, O.B., Olawuyi, O.J., Lawal, M., Ige, S.A., Mahamood, J., Afolabi, M.S., Azeez, M.A. and Abdulmaliq, S.Y. 2014. Genetic gains in three breeding eras of maize hybrids under low and optimum nitrogen fertilization. *Journal of Agricultural Sciences* **59**(3): 227–242.

Bryant-Schlobohm, R.B., Dhillon, J., Wehmeyer, G.B. and Raun, W.R. 2020. Wheat grain yield and nitrogen uptake as influenced by fertilizer placement depth. *Agrosystems, Geosciences and Environment* **3**: e20025. doi: 10.1002/agg2.20025

Department of Economics and Statistics (DES). 2021. Agricultural Statistics at a Glance.

Dhital, S. and Raun, W.R. 2016. Variability in optimum nitrogen rates for Maize. *Agronomy Journal* **108**(6): 2,165–2,173.

Dhillon, B.S., Sandhu, S.K. and Chawla, J.S. 2020. Maize for sustainable agriculture in changing climate maize for sustainable agriculture in changing climate. *(In) National Seminar on Maize for Crop Diversification under Changing Climatic Scenario*, pp. 4.

FAO 2018. Part-3: Feeding the World, Statistical Year Book of FAO of United Nation, Retrived on December 21, 2022, Retrieved from http://www.fao.org/3/%20i3107e/i3107e03.pdf

Govind, K.C., Karki, T.B., Shrestha, J. and Achhami, B.B. 2015. Status and prospects of maize research in Nepal. *Journal of Maize Research and Development* **1**(1): 1–9. doi: 10.3126/jmrd.v1i1.14239

Khan, G.R. and Akma, M. 2021. Nitrogen application rate and timing management for improved grain quality parameters of wheat crop. *Pakistan Journal of Agricultural Sciences* **58**: 1,141–1,153.

Onasanya, R.O., Aiyelari, O.P., Onasanya, A., Oikeh, S., Nwilene, F.E. and Oyelakin, O. 2009. Growth and yield response of maize (*Zea mays* L.) to different rates of nitrogen and phosphorus fertilizers in southern Nigeria. *World Journal of Agricultural Sciences* **5**(4): 400–407.

Sarangi, S.K., Singh, S., Srivastava, A.K., Choudhary, M., Mandal, U.K., Lama, T.D., Mahanta, K.K., Kumar, V., Sharma, P.C. and Ismail, A.M. 2020. Crop and residue management improves productivity and profitability of rice–maize system in salt-affected rainfed lowlands of East India. *Agronomy* **10**. doi: 10.3390/agronomy10122019.

Shrestha, J., Yadav, D.N., Amgain, L.P. and Sharma, J.P. 2018. Effects of nitrogen and plant density on maize (*Zea mays* L.) phenology and grain yield. *Current Agriculture Research Journal* **6**(2): 175–182.

Indian Journal of Agronomy **68** (4): 373–378 (December 2023)

Research Paper

Drip irrigation in maize (*Zea mays*)-based cropping systems

G.B. SHASHIDHARA[1]

University of Agricultural Sciences, Dharwad, Karnataka 580 005

Received: March 2022; Revised accepted: November 2023

ABSTRACT

A field experiment was conducted during 2015–16 and 2016–17 at the Irrigation Water Management Research Centre (University of Agricultural Sciences, Dharwad, Karnataka) Dharwad, Karnataka to estimate the productivity of drip irrigation for which maize (*Zea mays* L.) was grown in the rainy (*kharif*) season, followed by chickpea (*Cicer arietinum* L.) or bread wheat (*Triticum aestivum* L.) or field bean (*Phaseolus vulgaris* L.) in winter (*rabi*) season. The treatments comprised 3 levels of irrigation for maize, viz. 1.0 ET0 (the reference evapotranspiration); 0.8 ET0; and surface flooding (control); and 0.6 ET0 for chickpea, 0.9 ET0 for wheat, and 0.6 ET0 for field bean. The grain yield of maize was significantly higher in 1.0 ET0 (11.93 t/ha) than 0.8 ET0 (11.16 t/ha or the control (9.73 t/ha). In the winter, yields with drip irrigation were significantly higher by 32.06% in chickpea, 16.46% in wheat, and 26.10% in field bean; in terms of maize-kernel equivalent yield, chickpea (20 t/ha) and wheat (18.4 t/ha) proved superior to field bean. The highest water productivity (21.84 kg/m^3) was recorded in the maize-chickpea combination, which fetched the highest returns (about 2 Lakhs, or \$2475/ha), giving a benefit: cost (B:C) ratio of 4.13.

***Key words*:** Evapo-transpiration-based irrigation, Flood irrigation, Maize-based cropping systems, Maize-equivalent yield, Surface irritation water productivity

Malaprabha is one of the irrigation projects in Karnataka, although it offers no definite schedule or pattern for releasing water for irrigation. The quantity of water available for irrigation depends on the onset of the south-west monsoon, rainfall in the catchment area and the capacity of the reservoir. The most common cropping pattern in this command area comprises maize (early in *kharif*, or the rainy season, typically from June to September), followed by chickpea, wheat, safflower, sorghum, or sunflower (later in the *kharif* season), which, in turn, is followed by chickpea, wheat, sorghum, or safflower or a mixed/inter crop of chilli pepper, onion, and cotton. The main crop-growing period in the command area is from July to February: canal water for irrigation is usually available from the last week of August to December or, in a good season and if the dam is full, even up to the first half of January. Otherwise, water is available only for the winter (*rabi*) season, from September to December. In this agro-climatic zone (referred to as the Northern Dry Zone in India), it is possible to take an early crop if the area receives adequate (more than 100 mm) of rainfall from May to the first half of June; however, this is a gamble: the crops fail if the monsoon sets in late or weak in July and August, leading to a long, dry spell during the grand growth period of the crops at the time of peak water requirements.

Maize is the third most important food crop, after rice and wheat (USDA 2011), and considered a commercial crop with various industrial uses apart from its use as human food and also serves as feedstock for animals (Sarangi *et al*., 2020). Given the increasing demand for maize as both fresh and processed food, the challenge is to obtain higher yields from less water to maximize the crop's water productivity (WP). Proper scheduling of irrigation and applying fertilizers through drip irrigation (fertigation) are two major strategies to attain higher WP. Drip irrigation also known to have many advantages (Vijayakumar *et al*. 2010; Feleafel and Mirdad 2013; Deshmukh and Hardaha 2014), it saves water, expenditure on machinery, and labour, helps in applying fertilizers more accurately and uniformly, and increases the uptake of nutrients by roots. Zwart and Bastiaansen (2004) reported grain yields of maize as high as 1.1–2.7 kg/m^3 and attributed to climate, irrigation, and fertilizers. Their findings suggest that lowering irrigation volumes is the key to higher WP.

Despite such clear advantages of drip irrigation, no single system or design is available for drip irrigation suitable for the majority of crops grown by small farmers. The main reasons for drip irrigation not being popular among small farmers are its high initial cost and the difficulties

[1]**Corresponding author's Email:** shashidharagb@uasd.inat:
[1]Professor, Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka 580 005

posed by the network of pipes to cultural operations. The current available designs also require that the laterals and the drippers be changed for each crop. To overcome this constraint, a single system has been developed for the majority of crops grown in the study area (maize or sunflower followed by chickpea or wheat or field bean or groundnut or safflower or chilli + onion + cotton). The entire system remains above the ground so that it can be installed or dismantled easily and quickly.

With this background, new drip system was developed to be suitable for the majority of crops grown by the small farmers and was tested to quantify the benefits of drip irrigation for a maize-based cropping system in Karnataka, as applied in one catchment area, that served by the Malaprabha river and the reservoir fed by that river.

MATERIALS AND METHODS

A field experiment was conducted during 2015–16 and 2016–17 at the Irrigation Water Management Research Centre (15°342 N, 75°212 E and 578 m amsl) (University of Agricultural Sciences, Dharwad, Karnataka), Dharwad, Karnataka. The climate of the study site is semi-arid with annual precipitation of 560 mm and mean evaporation of 1626 mm (Table 1). The experimental fields had clayey soil (24.5% sand, 14.6% silt, and 60.9% clay) with an average bulk density of 1.4 Mg/m^3 to a depth of 90 cm, a *p*H of 8.5, and average electrical conductivity (EC) of 0.3 dS/m. The field capacity was 38.1% and the wilting point was 21.3%. The organic carbon content was 0.51%, available P was 37 kg/ha, and available K was 791 kg/ha

The irrigation lines rested on the soil surface and the network comprised sub-lines connected to the main line and laterals connected to the sub-lines. Each lateral was 10.8 m long, connected to the sub-line at intervals of 0.6 m, and was equipped with in-built emitters (discharging 4 litres of water per hour) spaced at intervals 0.4 m on the lateral lines.

Experimental design and treatments

The experiment was laid out in a strip plot design with 3 replications. Each main plot (the irrigation treatments) measured 68.04 m² and each subplot (the winter crops) was 22.68 m². The irrigation treatments for maize were 1.0 ET0 (I_1, the reference evapotranspiration), 0.8 ET0 (I_2), and surface irrigation (I_3, the farmers' method, which served as the control). After harvest of the maize crop, each main plot was divided into three subplots, one for each of the winter crops, namely chickpea, which was irrigated at 0.6 ET0; wheat, at 0.9 ET0; and field bean (as a relay crop) at 0.6 ET0 (ETo for this crops based on the experiments conducted and recommended from this centre). The dates of sowing and of harvest in both the years, 2015 and 2016,

Table 1. Rainfall and number of rainy days (in 2015 and 2016 and average values) at Irrigation Water Management Research, Belavatagi research station, Karnataka

Month	Normal rainfall 1985–2016	Normal no. of rainy days 1993–2016	Rainfall (mm) 2015	No. of rainy days 2015	Deficit/Excess rainfall (mm) 2015	Deficit (%) 2015	Rainfall (mm) 2016	No. of rainy days 2016	Deficit/Excess rainfall (mm) 2016	Deficit (%) 2016
Jan.	1.93	2.80	0.0	0.0	“1.93	100.00	0.0	0.0	“01.93	100.00
Feb.	1.36	0.27	0.0	0.0	“1.36	100.00	0.0	0.0	“01.36	100.00
Mar.	13.09	1.68	27.8	1.0	14.71	Excess	0.0	0.0	“13.09	100.00
Apr.	30.20	3.50	12.2	1.0	“18.00	59.60	09.4	1.0	“20.80	68.87
May	35.10	5.67	30.1	4.0	“05.00	14.24	88.2	9.0	53.10	Excess
June	86.23	4.44	120.2	7.0	33.97	Excess	78.2	4.0	“08.03	9.31
July	85.83	6.12	46.0	3.0	“39.83	46.40	62.7	10.0	“23.13	26.95
Aug.	80.53	5.84	35.0	7.0	“45.53	56.53	29.3	4.0	“51.23	63.62
Sept.	128.47	6.88	156.8	7.0	28.33	Excess	51.4	4.0	“77.07	59.99
Oct.	68.25	1.88	151.8	4.0	83.55	Excess	12.0	1.0	“56.25	82.42
Nov.	31.06	0.57	3.0	0.0	“28.06	90.30	0.0	0.0	“31.06	100.00
Dec.	4.91	0.63	0.0	0.0	“04.91	100.00	0.0	0.0	“04.91	100.00
Total	566.96	4.27	582.9	34.0	15.94	2.81% Excess	331.20	33.0	“235.76	41.58

are given in Table 2.

Fertilizers were applied to soil by conventional method of application as per the recommended doses (per hectare) for maize (150 kg of N, 76.5 kg of P_2O_5, and 67.5 kg of K_2O), chickpea (25 kg of N and 50 kg of P_2O_5), wheat (100 kg of N, 75 kg of P_2O_5, and 50 kg of K_2O), and field bean (25 kg of N and 50 kg of P_2O_5). Plant population was maintained at 100% during both the years. Maize was irrigated every 4 days in *kharif* and the other crops were irrigated every 7 days for *rabi* crops in all the drip irrigation treatments.

Each year, maize was irrigated 18 times and the winter crops were irrigated 12 times (Table 3). The total volume of water amounted (at 1.0 ETo) was 800 mm for the maize-chickpea system, 942 mm for the maize-wheat system, and 828 mm for the maize-field bean system. The corresponding amounts supplied through the surface method were 1013 mm, 1163 mm and 953 mm (pooled data). In both the yeas, the effective rainfall was 194, 92.7 mm received during *kharif* 2015 and 2016, and there was no rainfall during *rabi* seasons of both the years. Therefore, most of the rainfall received during the crop growth period was insufficient, and the crops were sustained by irrigation.

The amount of irrigation water applied through drip irrigation was calculated as:

$$Wa = \frac{\mathrm{IETo}}{\mathrm{Ea}} + \mathrm{LR}$$

where I, the empirical irrigation level (1.0 ET0 and 0.8 ET0, respectively, for the treatments I_1 and I_2); Ea, irrigation efficiency of the system determined at the beginning of the season as 0.8; and LR, the quantity required to compensate for water lost through leaching (assumed to 10% in each round of irrigation).

The reference crop evapo-transpiration (ET0) was calculated as:

ET0 = Ep. Kp

where, EP, the cumulative evaporation to be considered for choosing the irrigation interval and Kp, the pan evaporation coefficient (taken as 0.75 for the experimental site). Evaporation was measured daily from the standard Class A pan evaporation tank placed close to the experimental field.

The duration of irrigation was calculated as:

$$t = \frac{\mathrm{Wa\ A}}{q}$$

where, t, the duration of irrigation in hours; Wa, the depth of applied irrigation water in millimetres; A, the area, in square metres, wetted by emitters; and q, the rate of discharge of water from each emitter (litre/h).

Water productivity was determined to evaluate the benefit derived from irrigation and can be defined as the amount of grain yield a cubic metre of water may produce; the values of WP (kg/m^3) were determined by dividing the grain yield (kg/ha) by the total amount of irrigation water (m^3/ha) (Table 4). The data were subjected to analysis of variance, and mean values from the different treatments were compared using the test of least significant difference at 0.05 probability level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Grain yield

Maize grain yield (Table 4) in 1.0 ET0 was significantly higher than 0.8 ET0 and the control in both years. Pooled data for the two years shows that compared to the yield in the farmers' method, or the control, the yield in 1.0 ET0 was greater by 22.6% and the yield in 0.8 ET0 was higher by 14.6%. The same pattern was seen in the winter crops, the corresponding higher yields being 32.0% greater in chickpea, 16.5% in wheat, and 26.1% in field bean. The higher yields were due to easy access to moisture and nutrients enabled by the more controlled irrigation, which supplied the required quantity at frequent intervals to match the actual water needs of the crops at various stages. Although drip irrigation wetted only a small zone of the soil around the plant, the method ensured that soil moisture was always maintained close to field capacity. This continued supply also rendered ineffective most of the rainfall received during the crop growth period. Similar increases in the yield of maize with drip irrigation were reported by Islam *et al.,* (2006) and Anitta Fanish (2013).

Water productivity (WP)

Water productivity was significantly higher with drip irrigation in both seasons (Table 4). In maize, WUE

Table 2. Crops, cultivars and dates of sowing and harvest during 2015–16 and 2016–17

Crop and cultivar	2015–16		2016–17	
	Sowing	Harvesting	Sowing	Harvesting
Rainy season				
Maize (Cargil 900M)	10 Aug.	18 Nov.	13 July	4 Nov.
Winter season				
Chickpea (JG-11)	24 Nov.	12 Mar.	7 Nov.	20 Mar.
Wheat (UAS-334)	24 Nov.	12 Mar.	7 Nov.	28 Feb.
Field bean (Hebbal Avare)	29 Oct.	28 Feb.	21 Oct.	21 Feb.

Table 3. Total quantity of irrigation given through drip system and farmer's method (surface flooding)

Treatment (ETo is reference evapotranspiration)		No. of irrigation	Total amount of water applied (mm) (rainfall + drip)								
			Maize-chickpea @0.6 ETo			Maize-wheat @0.9 ETo			Maize-field bean @0.6 ETo		
			Maize	Chickpea	Total	Maize	Wheat	Total	Maize	Field bean	Total
Maize @1.0 ETo	2015	18 + 12	459	220	679	459	331	790	459	164	663
	2016	18 + 12	553	368	921	553	541	1094	676	355	1031
	Pooled	18 + 12	506	294	800	506	436	942	568	260	828
Maize @0.8 ETo	2015	18 + 12	409	220	629	409	331	740	409	164	573
	2016	18 + 12	469	368	837	469	541	1010	469	354	823
	Pooled	18 + 12	439	294	733	439	436	875	439	259	698
Maize (surface flooding)	2015	5 + 5	690	300	990	690	420	1110	690	240	930
	2016	5 + 5	676	360	1036	676	540	1216	676	300	976
	Pooled	5 + 5	683	330	1013	683	480	1163	683	270	953

Table 4. Yield and water productivity of crops irrigated by the drip method in maize-based cropping system in Malaprabha command area

Treatment (Horizontal strips) (ETo is reference evapotranspiration)	Yield							Water Productivity (kg/m³)						
	Maize (t/ha)			*Rabi* (kg/ha) (vertical strips)				Maize			*Rabi*			
	2015	2016	pooled	Crop	2015	2016	Pooled	2015	2016	Pooled	Crop	2015	2016	Pooled
Maize @1.0 ETo	9.96	13.97	11.93	Chickpea	2925	2776	2850	21.72ab	25.15ab	23.44ab	Chickpea	13.26	7.54	10.40
				Wheat	3530	4729	4130				Wheat	10.69	8.74	9.72
				Field bean	1517	1787	1652				Field bean	07.44	5.04	6.24
Maize @0.8 ETo	9.29	13.02	11.16	Chickpea	2796	233.9	2568	22.22 a	27.77 a	24.99 a	Chickpea	12.68	6. 38	9.53
				Wheat	3329	4430	3880				Wheat	10.09	8.19	9.14
				Field bean	1335	1636	1486				Field bean	6.55	4.62	5.58
Maize (Surface flooding)	8.05	11.3.	9.73	Chickpea	2207	2109	2158	11.73c	20.39c	16.06c	Chickpea	7.36	5.86	6.61
				Wheat	3176	3915	3546				Wheat	7.56	7.25	7.41
				Field bean	1203	1416	1310				Field bean	5.01	4.72	4.87
SEm±	0.25	0.34	0.28		58	177	97	T test	T test	T test	SEm±	0.23	0.403	0.48
CD (P=0.05)	0.89	1.19	0.99		175	350	291	S	S	S	CD (P=0.05)	0.68	1.17	2.47

Chickpea @0.6 ETo; wheat @0.9 ETo; and field bean @0.6 ETo. S, Significant.

Table 5. Yield, water use, water productivity, water saving and economics of maize in *kharif* followed by chickpea, wheat, or field bean in *rabi*

Treatment (ETo is reference evapotranspiration)	Maize grain equivalent yield (t/ha)	Total water use (mm)	Water Productivity (kg/m³)	Water saving (%)	Net returns (/ha)	Benefit to cost ratio	Superiority over existing farmers' method
Horizontal strip: maize grown in *kharif* with different irrigation levels							
Maize @1.0 ETo	19.4	857	22.64	17.87	213,838	4.73	₹51,194 profit with 17.87% water saving over farmers' method
Maize @0.8 ETo	17.5	769	22.76	26.28	187,219	4.26	₹24,575 profit with 26.28% water saving over farmers' method
Maize (surface flooding)	15.7	1043	15.09	-	162,644	3.84	-
SEm±	0.33				4,642.29	0.08	
CD (P=0.05)	1.30				18,228	0.31	
Vertical strip: *rabi* crops grown after maize with different irrigation levels							
Maize-chickpea @ 0.6 ETo	18.5	849	21.84	14.76	196,805	4.13	₹11,940 profit over maize-wheat system with 14.76% saving of water
Maize-wheat @0.9 ETo	17.5	993	17.64	-	184,865	4.06	
Maize-field bean @0.6 ETo	16.5	826	20.08	20.21	182,031	4.62	₹2,834 profit over maize-wheat system with 20.21% saving of water
SEm±	0.40				5,650.76	0.10	
CD (P=0.05)	1.58				22,188	0.39	
Interactions effect of *kharif* followed by *rabi* crops (H × V)							
Maize-chickpea @ 0.6 ETo	20.6	800	25.83	19.00	226,459	4.61	₹65,227 over maize–wheat system and ₹ 57,055 profit over maize-chickpea, farmers' method under drip with 19–27.5% saving of water
Maize-wheat @0.9 ETo	19.1	942	20.37	27.50	208,226	4.45	
Maize-field bean @0.6 ETo	18.3	828	22.18	28.80	206,828	5.11	
Maize-chickpea @0.6 ETo	18.3	733	25.08	36.69	194,552	4.10	₹25,148 over maize-wheat system and ₹33,370 profit over maize-chickpea farmers' method under drip with 3.6.69–24.76% saving of water
Maize-wheat @0.9 ETo	17.5	875	20.05	24.76	185,186	4.07	
Maize-field bean @0.6 ETo	16.5	698	23.76	39.98	181,919	4.62	
Maize-chickpea (surface flooding)	16.5	1013	16.38		169,404	3.70	-
Maize-wheat (surface flooding)	15.8	1163	13.61		161,182	3.67	-
Maize-field bean (surface flooding)	14.8	953	15.56		157,346	4.13	
SEm±	0.15				2103	0.04	
CD (P=0.05)	0.49				6859	0.13	

recorded in 0.8 ET0 (24.99 kg/m^3) was higher than that in the control (16.06 kg/m^3). The same pattern was repeated in the winter crops. The higher WP was owing to the considerable saving of irrigation water, greater yields, and higher nutrient-use efficiency (Ramah, 2008). Increase in irrigation volume not only failed to elicit any corresponding increase in the marketable yield of crops but also lowered the production efficiency of irrigation significantly (Imtiyaz *et al*., 2000). Ardell (2006) reported that application of nitrogen and phosphorus usually results in higher yields, thereby increasing the crop WUE. Adequate levels of essential plant nutrients are needed for higher yields and higher WUE.

Maize-grain-equivalent yield and economic parameters

Overall, drip irrigation at 1.0 ET0 resulted in significantly higher maize-grain-equivalent yield (19.4 t/ha) compared to 0.8 ET0 (17.5 t/ha) and control (15.8 t/ha) (Table 5). The same pattern was seen among the three winter crops that followed maize. However, the result of the interaction between the level of irrigation and the crop showed that the highest equivalent yield (20.6 t/ha) obtained from maize with drip irrigation at 1.0 ET0 followed by chickpea at 0.6 ET0. This combination (maize-chickpea) is recommended for the region if water supply is limited. However, all the three winter crops are grown in the Malaprabha command area, and farmers can make their choice going by market demand and the availability of seeds and other resources, so long as they switch to drip irrigation.

The economics of drip fertigation in maize-based cropping systems are presented in Table 5. Although the initial capital investment was high for a drip fertigation system, the benefits outweigh the costs given the long life of the system. Secondly, although the cost of cultivation was generally higher with drip irrigation, so were the net returns per hectare from maize at 1.0 ET0 followed by chickpea at 0.6 ET0 (about ₹2 Lakhs, or \$2475/ha), at a B:C ratio of 4.61 and 19% savings in the volume of water.

Drip fertigation uses both water and applied nutrients more efficiently, thereby achieving higher productivity. Drip irrigation is the need of the hour especially in areas with water deficit and can overcome the constraints posed by an uncertain monsoon and irregular release of water from dams. By storing water (*in situ*) in farm ponds and by supplying it through the drip system, farmers can grow two or three crops in a year. The drip system should not be viewed merely from the economic point of view. Given the shrinking availability of land for cultivation and the diversion of available water to non-agricultural uses, it is of paramount importance that water made available for agriculture be used as efficiently by adopting such techniques as drip irrigation. In areas of acute scarcity of water, drip irrigation is the only way to enhance crop productivity.

Switching from surface irrigation to drip irrigation increased the income from maize in the rainy season and wheat in winter by ₹ 65,227/ha; increased the amount of water saved by 27.5%; and earned a net profit of ₹ 57,055/ha. Growing either chickpea or field bean in winter also led to higher profits and greater savings of water. As all these crop combinations are common in the command area, the crop to follow maize can be chosen based on the market price to maximize profits.

REFERENCES

Anitta Fanish, S. 2013. Influence of drip fertigation on water productivity and profitability of maize: *African Journal of Agriculture Research* **8**(28): 3,757–3,763.

Ardell, D.H. 2006. Water use efficiency under different cropping situation. *Annal of Agriculture Research* **27**(5): 115–118.

Deshmukh, G. and Hardaha, M.K. 2014. Effects of irrigation and fertigation scheduling under drip irrigation in papaya. *Journal of Agriculture Research* **1**(4): 216–220.

Feleafel, M.N. and Mirdad, Z.M. 2013. Optimizing the nitrogen, phosphorus and potash fertigation rates and frequency for eggplant in arid regions. *International Journal of Agriculture Biology* **15**(4): 737–742.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedure for Agricultural Research*. John Willey and Sons, New York.

Imtiyaz, M, Mgadla, N.P., Manase, S.K, Chendo, K. and Mothobi, E.O. 2000. Yield and economic return of vegetable crops under variable irrigation. *Irrigation Science* **19**: 87–93.

Islam, M.N, Haque, M.M. and Hamid, A. 2006, Planting arrangement and population density effects on the physiological attributes and productivity of maize-bush bean intercropping system. *Bangladesh Journal of Agriculture Research* **31**(3): 353–364.

Ramah, K. 2008. 'Study on drip irrigation in maize (*Zea mays* L.) based cropping system'. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Sarangi, S.K., Singh, S., Srivastava, A.K., Choudhary, M., Mandal, U.K., Lama, T.D., Mahanta, K.K., Kumar, V., Sharma, P.C. and Ismail, A.M. 2020. Crop and residue management improves productivity and profitability of rice-maize system in salt-affected rainfed lowlands of East India. *Agronomy* **10**(2019). DOI: 10.3390/agronomy10122019

USDA. 2011. Grain: World markets and trade. Foreign Agriculture Service, Circular Series FG 09-11. Foreign Agricultural Service, United States Department of Agriculture. http://www.fas.usda.gov/psdonline/circulars/grain.pdf

Vijayakumar, G., Tamilmani, D. and Selvaraj, P.K. 2010. Irrigation and fertigation scheduling under drip irrigation in brinjal (*Solanum melongena* L.) crop. *International Journal of Bioresource Management* **1**(2): 72–76.

Zwart, S.J. and Bastiaansen, W.G.M. 2004. Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. *Journal of Agriculture Water Management* **69**: 115–133.

Indian Journal of Agronomy **68** (4): 379–385 (December 2023)

Research Paper

Assessment of precise nutrient management through nutrient expert on productivity and profitability of zero-till maize

SEEMA SEPAT[1], BHAGYSHREE PHOGAT[2], R.S. BANA[3], DINESH KUMAR[4] AND S.L. MEENA[5]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Received: July 2022; Revised accepted: October 2023

ABSTRACT

An experiment was conducted during the rainy (*kharif*) season of 2017 and 2018 at the ICAR-Indian Agricultural Research Institute, New Delhi, to evaluate the effect of tillage and nutrient-management options on yield, nutrient uptake, residual soil-fertility status, and enzymatic activities in maize (*Zea mays* L.). The zero-tillage with crop residue at 3.5 t/ha (ZT + R) and conventional tillage with crop residue at 3.5 t/ha (CT + R) enhanced the grain yield (6.2–17.0%) of maize compared to CT without residue (4.40 t/ha). High cost of cultivation was recorded in CT + R (44.8×10^3 ₹/ha), while high net returns were found in ZT + R (37.6×10^3 ₹/ha). In ZT + R, the addition of wheat residue enhanced N, P, and K uptake in grain by 19.41, 12.81 and 13.92%, respectively over CT. Available N (182 kg/ha), available P (13.8 kg/ha), and exchangeable K (318 kg/ha) were found highest with ZT + R. Nutrient expert system (NES) enhanced the grain yield (5.30 t/ha) and net returns (43.0×10^3 ₹/ha) compared to no application of nutrients (control) (3.35 t/ha and 17.9×10^3 ₹/ha) and recommended dose of fertilizer (RDF) (4.70 t/ha and 34.8×10^3 ₹/ha). Higher activity of dehydrogenase (DHA) (25.9 TPF µg/g/h) and microbial biomass C (130 µg/g) were found with NES. An increase of 57.96–58.4% in N uptake was found with NES over RDF (80.0 kg/ha). The nutrient expert system (NES) and 125% of RDF left higher amount of residual N, P and K in soil than the control. Overall, nutrient expert system under zero-tillage with crop residue at 3.5 t/ha can increase the productivity and profitability in maize.

Key words: Conservation agriculture, Maize, Nutrient expert, Nutrient uptake, Precision crop nutrition, Profit, Yield

In India, maize (*Zea mays* L.) is the third most important crop after rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.), having a 9.2 mha area with a production of 27.3 mt (FAO, 2022). It is considered as a futuristic crop owing to its high yield potential and emerging demand in poultry and starch industries. Maize productivity is low in India (3.5 t/ha) as compared to the USA (7.89 t/ha) and China (6.32 t/ha)(IIMR 2020). The actual maize yield in irrigated ecologies have varied yield gaps due to low yielding genotypes, faulty agronomic management practices including imbalanced, inadequate amount of fertilization and intensive tillage causing low nutrient supplying capacity and fertility in soil. To address these issues, Conservation agriculture (CA), has been promoted to achieve sustainability in intensively cultivated cereal-based systems (Pasuquin *et al.,* 2014). Adoption of zero-tillage (ZT) enhanced the productivity and profitability in rice–wheat (Pampolina *et al*., 2012) and maize–wheat (Sepat *et al*., 2019) cropping systems. In addition, retention of residue on soil surface contributed to high soil organic C (SOC) by 3.4–6.7% in cereal-based system (Sepat and Rana, 2013). In CA, heavy loads of residues are retained (3 to 9 t/ha). So, there are chances that the required amount of nutrients may be less (Sepat *et al*., 2014) or higher (Singh *et al*., 2016).

Site-specific nutrient management (SSNM)-based on crop demand and supply enhances crop productivity, soil-nutrient status, and nutrient-use efficiency as nutrient recommendations are based on soil-test values. In India, nutrient management is widely based on blanket recommendations though scientific recommendations are based on soil-test values, accounting for variety potential or soil-fertility status. Therefore, efficiency of applied nutrient is static as *in-situ* nutrient losses are high from the system.

[2]**Corresponding author's Email:** seemasepat12@gmail.com & phogat10111994@gmail.com

[1,3]Senior Scientist, [2]Ph.D. Scholar, Swami Keshwanand Rajasthan Agriculture University Bikaner, Rajasthan 334 001; [4,5]Principal Scientist, ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Nutrient expert system (NES) could solve drift in resources for attaining higher yield, a software based on decision-support system (DSS) developed by the International Plant Nutrition Institute for SSNM in cereal-based systems (Pampolina *et al*., 2012). In NES, nutrient management is based on principles of 4R: i.e., applying right source of nutrient at right rate and time and at right place (Pasuquin *et al.,* 2014). In maize, NES enhanced yield (0.9–1.2 t/ha) and profit (US$ 270–379/ha) of farmers in Indonesia and the Philippines (Pampolina *et al*., 2012). Here, estimation of crop need-based nutrient supplying as per target yield is done for nutrient recommendations taking into account of indigenous nutrient-supplying capacity of soil, yield targets capable to maximize yields with restoration of soil fertility. In India, research findings indicated that, on an average, farmer uses 180, 200, 60, 80 and 20–40 kg/ha of N, P_2O_5, and K_2O respectively. However, fertilizer application based on NE reduced N, P_2O_5, and K_2O requirement by 20–30, 35–45 and 40–60 kg/ha respectively. So, saving of 17, 56 and 58% in fertilizer use was found for maize (Singh *et al*., 2016). There is a need to evaluate and consolidate validity of NES in North–Western part of India where maize is considered as futuristic crop for the replacement of rice. Under such circumstances, nutrient-management through advance tool is required to maximize yield with nutrient saving. In maize, economical aspect of yield and nutrient-use efficiency need to be rationalized with NES under conservation agriculture. Therefore, an experiment was carried out to standardize NES with varying tillage and nutrient management for yield, net benefit and nutrient uptake.

MATERIALS AND METHODS

An experiment was conducted during the rainy (*kharif*) season of 2017 and 2018 at the research farm of the ICAR–Indian Agricultural Research Institute, New Delhi, (28°40' N, 77°12' E, 228.6 m mean sea-level). The site falls in Trans Indo-Gangetic Plains agro-climatic zone, with subtropical and semi-arid climate, having warm summers and cold winters, with mean annual maximum and minimum temperatures of 40.5° C and 6.5° C, respectively. The mean annual rainfall is 670 mm and approximately 70–80% occurred during 3 months (July–September). The total rainfall received in 2017 and 2018 was 990.9 and 992.2 mm respectively. The mean maximum and minimum temperatures were 33 and 22°C. Soil has sandy loam (Inceptisols) texture, having *p*H (7.3), electricity conductivity (0.45 dS/m) and cation-exchange capacity (10.8 cmol/ kg) in 0–15 cm depth. It has soil organic carbon of 0.38%, available N, P and K of 162 kg/ha, 13.5 kg/ha and 280 kg/ha. Experiment was laid-out in split-plot design with 3 replications. In main plot, 4 tillage practices, viz. conventional tillage (CT), CT with crop residue at 3.5 t/ha (CT + R), zero-tillage (ZT - R) and ZT with crop residue at 3.5 t/ha (ZT + R), and 4 nutrient-management practices such as no nutrient application (control), recommended dose of fertilizers (RDF), 125% of RDF and NES-based nutrient doses were taken in subplots. An additional 25% of RDN was taken considering the higher nutrient requirement in maize in lieu of low soil fertility to achieve higher productivity. Maize (variety 'PHM 1') was sown in July at row spacing of 67.5 cm × 15 cm using a seed rate of 20 kg/ha. Harvesting was done manually in October, and grain yield as per plot was weighted at moisture content of 12.5 %. Soil samples were taken from each plot for nutrient uptake analysis after maize harvesting. Soil samples were stored at 5°C, and prior to biological analyses equilibrated at 22–25°C. Soil dehydrogenase activity (Cassida *et al*., 1964) and soil microbial biomass-C was determined by fumigation method (Vance *et al*., 1987).

Standardization of nutrient doses through nutrient expert system

Nutrient expert is easy to operate computer-based tool, given agronomic practices followed for crop production such as i) previous history of cropping systems, ii) soil-fertility status (*p*H, SOC, N, P and K), iii) agronomic management practices, iv) no. of tillage operations (either intensive or zero tillage), v) number of irrigations and stages of crop for irrigation, vi) variety taken and targeted yield, vii) amount of farm yard manure, compost or N, P and K, and micronutrient, viii) residue or no-residue applications, ix) method of application of N, P and K. Based on these inputs, NES gives precise amount of nutrients and stages when it needs to be applied to achieve target yield. Here, targeted yield of maize was taken 7 t/ha as per the potential of variety to calculate N, P and K recommendation (Table 1). In maize, half dose of N, and full dose P and K were applied at the time of sowing, while remaining half dose of N was applied in 2-equal splits at knee-high and tasseling stage.

RESULTS AND DISCUSSION

Yield attributes and yield

Tillage practices significantly influenced the grain rows/cob in 2018 and grains/grain row in 2017 and 2018 (Table 2). Decomposition of residue enhanced the available soil water and plant nutrients to maize crop (Sepat *et al.,* 2019). Therefore, ZT + R and CT + R were found at par for grain rows/cob (15.45 and 14.6) and grains/grain row (26.35 and 25.55), followed by CT (13.8 and 23.6). The ZT–R recorded the lowest values for grain rows/cob and grains/grain row as no residue retention enhanced the soil-moisture depletion, and thereby low nutrient utilization resulted in formation of low photosynthates for formation of

Table 1. Amount of nutrients (N : P : and K) in maize crop during 2017 and 2018

Parameters	ZT + R	CT + R	CT	ZT – R
Control	–	–	–	–
RDF	150 : 80 : 60	150 : 80 : 60	150 : 80 : 60	150 : 80 : 60
125% of RDF	187 : 100 : 75	187 : 100 : 75	187 : 100 : 75	187 : 100 : 75
NES	167 : 54 : 71	167 : 54 : 71	172 : 60 : 80	172 : 60 : 80

RDF, Recommended dose of fertilizer; NES, nutrient expert system; ZT + R, zero-tillage with crop residue @ 3.5 t/ha; CT + R, conventional tillage + crop residue @ 3.5 t/ha; CT, conventional tillage; ZT-R, zero-tillage without crop residue.

Table 2. Effect of tillage and nutrient management on yield attributes of maize in 2017 and 2018

Treatment	Cob length (cm)		Grain rows/cob		Grains/grain row		Test weight (g)	
	2017	2018	2017	2018	2017	2018	2017	2018
Tillage and crop establishment								
CT	16.2	15.8	14.2	13.4	24.3	22.9	219	224
CT + R	16.0	16.1	14.2	15.0	26.9	24.2	221	227
ZT –R	15.9	15.3	12.5	12.2	22.8	20.8	215	220
ZT + R	16.6	15.6	14.7	16.2	27.5	25.2	222	231
SEm±	0.24	0.25	0.32	0.36	0.28	0.31	6.7	7.2
CD (P=0.05)	NS	NS	1.02	1.15	0.90	0.99	NS	NS
Nutrient management								
Control	14.5	13.8	9.0	11.5	18.3	19.0	202	205
RDF	16.2	16.2	13.3	13.7	24.0	23.5	220	227
125% RDF	17.0	16.4	16.0	15.2	29.0	25.3	225	232
NES	17.0	16.4	17.3	16.4	30.2	25.3	230	238
SEm±	0.11	0.16	0.22	0.28	0.18	0.22	4.3	3.2
CD (P=0.05)	0.35	0.51	0.70	0.90	0.58	0.70	13.7	9.92

Details of treatments are given under Materials and Methods

higher grains. Cob length and test weight of maize were not influenced with tillage practices.

Nutrient-management options significantly influenced all the yield parameters of maize, viz. cob length, grain rows/cob, grains/grain row and test weight, in maize during 2017 and 2018 (Table 2). In maize, adequate supply of N, P and K enhanced the photosynthates formation and accumulation (Singh *et al.,* 2016), which resulted in increased cob length (16.2–17.0 cm), grain rows/cob (13.4–17.3), grains/grain row (23.5–30.2) compared to the control. A higher amount of K application through NES attributed to higher cell-division and turgidity, leading to increased grain weight in maize. NES and 125% of RDF remained at par for cob length, grain rows/cob, grains/grain row and test weight in both the years. The NES registered an increase of 4.9, 6.4, 5.5 and 15.2%, respectively, for cob length, grain rows/cob, grains/grain row and test weight compared to RDF over the years. A significant influence of tillage practices was observed on grain, straw and biological yields of maize in 2017 and 2018 (Table 3). The ZT + R resulted higher grain (5.2 t/ha), straw (6.3 t/ha) and biological yields (11.5 t/ha), followed by CT + R (4.85, 6.0 and 10.85 t/ha) and CT (4.4, 5.5 and 9.9 t/ha). In ZT, retention of residue enhanced the microbial parameters, viz. microbial biomass C and dehydrogenase activity in soil. Therefore, a higher activity of soil microbial community in ZT enhanced the mineralization of nutrients and efficient utilization to maize crop (Sepat *et al*., 2014) which gave additional yield compared to CT. In 2017 and 2018, an increase of 20.9 and 13.3%, respectively was noted in grain yield with ZT + R (5.2 and 5.1 t/ha) over CT (4.3 and 4.5 t/ha). Interaction of tillage and nutrient-management options on grain yield of maize was found significant during 2018 (Table 6). The ZT + R with NES (6.01 t/ha) recorded at par yield to ZT + R with 125% of RDF followed by CT + R with NES.

No NPK application with ZT – R (3.12 t/ha) and CT (3.15 t/ha) recorded the lowest grain yield compared to ZT + R (3.58 t/ha) and CT + R (3.75 t/ha).

A total of 14.5 kg/ha wheat residues were added in CT + R and ZT + R grown maize in 2 years. The CT, CT + R and ZT + R were found at par with biological yield of maize during both years. No residue retention in ZT was found worst practice and recorded the lowest grain yield (4.05 t/ha) and biological yield (9.3 t/ha) during 2017 and 2018.

In 2017 and 2018, NES gave the highest grain yield (5.2 and 5.4 t/ha) over RDF (4.6 and 4.8 t/ha) (Table 3). In RDF (150 kg N, 80 kg P_2O_5 and 60 kgK_2O/ha), pre-determined rates of major nutrients remained constant over the time. An additional dose of applied 17–22 kg N and 15–20 kg K_2O/ha was found beneficial for yield enhancement in NES as compared to RDF. It was proven based on the findings that for yield enhancement, nutrients need to be based on balanced amount depending on crop demand and supply (Sepat *et al*., 2015). A higher amount of 20 kg N, 20 kg P_2O_5 and 15–20 kg K_2O/ha in 125% of RDF was applied compared to NES. However, both NES and 125% of RDF remained at par for grain, straw and biological yields of maize in 2017 and 2018.

In 125% of RDF, an additional amount of nutrient increased the utilization pattern, thereby enhanced the grain yield and found comparable with NES. However, in NES, nutrient uptake was efficiently converted to achieve production with minimal nutrient losses over to 125% of RDF.

Straw and biological yields followed the same trend as in the case of grain yield of maize. Biological yield exhibited an increase of 35.4–54.5% through nutrient application compared with the control. Besides, an increase of 13–12.5% was recorded with NES over to RDF. It highlights that higher amount of fertilizer through 125% of RDF was not efficiently utilized by the maize crop. The NES gives effective fertilizer recommendations by considering yield responses and contribution of nutrients from indigenous sources (Sepat *et al*., 2019).

Economics

Higher number of tillage operations in CT + R and ZT + R incurred high cost of cultivation due to more consumption of inputs (diesel and labour) over to CT. In ZT + R, tillage was confined to seed sowing; however, cost was highly inculcated mainly owing to precious wheat straw retention. Hence, higher cost of cultivation was recorded in ZT + R over to all tillage combination. The ZT without any cost of tillage and residue recorded the lowest cost of cultivation.

High grain yield compensated high economic cost of cultivation, and therefore higher gross and net returns were recorded (71.8 and 37.6 × 10^3 ₹/ha) in ZT + R. The second practice was CT + R in terms of high gross and net returns of maize (67.6 and 28.8 × 10^3 ₹/ha). An additional net income of 2900 ₹/ha was recorded with ZT + R and CT + R as compared to CT (34.7 × 10^3 ₹/ha). This highlights that if suitable machinery is available than ZT + R or CT + R can be adopted by the farmers as both are equally economically beneficial.

Nutrient application had profound effect on net returns of maize (Table 4). An additional amount of nutrients through 125% of RDF (37.6 × 10^3 ₹/ha) and NES (37.3 × 10^3 ₹/ha) escalated the cost of cultivation compared to RDF (36.7 × 10^3 ₹/ha). In general, nutrient application mounted the cost of cultivation by 4,000/- /ha over control (33.5 × 10^3 ₹/ha). However, higher grain and straw yield with fertilization recorded higher gross (70.2 × 10^3 ₹/ha) and net returns (39.1 × 10^3 ₹/ha) compared to control (46.7

Table 3. Effect of tillage and nutrient management on yield and economics of maize in 2017 and 2018

Treatment	Yield (t/ha)						Cost of cultivation (×10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Nitrogen–use efficiency (kg grain/kg N applied)	
	Grain		Stover		Biological						
	2017	2018	2017	2018	2017	2018	Mean of two years*			2017	2018
Tillage and crop establishment											
CT	4.3	4.5	5.4	5.6	9.8	10.0	32.1	61.4	34.7	20.9	22.0
CT + R	4.8	4.9	6.0	6.0	10.8	10.9	44.8	67.6	28.8	23.2	23.2
ZT –R	3.9	4.2	5.0	5.5	8.8	9.8	27.8	56.6	34.1	18.3	20.3
ZT + R	5.2	5.1	6.4	6.2	11.6	11.3	40.5	71.8	37.6	25.4	25.1
SEm±	0.24	0.20	0.11	0.13	0.32	0.36	–	2.89	2.89	0.45	0.51
CD (P=0.05)	0.74	0.62	0.33	0.40	0.99	1.15	–	9.26	9.26	1.56	1.75
Nutrient management											
Control	3.4	3.4	5.0	4.4	8.4	7.7	33.5	46.7	17.9	-	-
RDF	4.6	4.8	5.7	5.9	10.3	10.7	36.7	65.7	34.8	30.6	32.0
125% RDF	5.0	5.2	6.0	6.4	11.0	11.6	37.6	71.1	39.6	26.7	27.6
NES	5.2	5.4	6.1	6.6	11.3	12.0	37.3	73.9	43.0	30.5	31.1
SEm±	0.14	0.13	0.09	0.11	0.30	0.32	–	1.56	1.56	0.31	0.37
CD (P=0.05)	0.43	0.40	0.28	0.33	0.93	0.99	–	4.81	4.81	0.91	1.08

Details of treatments are given under Materials and Methods
*Mean data of 2017 and 2018

Table 4. Effect of tillage and nutrient management on nutrient uptake (kg/ha) in maize in 2017 and 2018

Treatment	N (kg/ha)				P (kg/ha)				K (kg/ha)			
	Grain		Total		Grain		Total		Grain		Total	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Tillage and crop establishment												
CT	68.8	78.0	109	102	23.76	24.85	35.36	37.75	28.1	28.9	131	122
CT + R	79.2	83.5	112	112	25.34	26.17	38.84	39.77	30.6	31.6	139	130
ZT –R	58.8	64.3	90.5	101	21.78	24.10	32.68	35.90	26.1	27.6	114	115
ZT + R	88.3	87.0	120	116	27.68	26.83	41.58	40.53	32.4	32.4	142	148
SEm±	1.82	1.76	4.2	3.8	0.18	0.22	0.36	0.38	0.38	0.42	3.92	3.65
CD (P=0.05)	5.82	5.63	13.4	12.2	0.58	0.70	1.15	1.25	1.22	1.34	12.64	11.68
Nutrient management												
Control	49.6	47.5	80.4	77.0	19.82	18.91	29.82	29.91	22.9	22.2	112.8	109.2
RDF	72.7	79.7	103	112	24.60	25.36	36.80	37.66	28.6	30.1	130	130
125% RDF	83.3	89.4	123	120	26.45	28.25	39.85	42.15	32.2	32.9	140	132
NES	89.4	96.1	127	122	28.20	29.44	42.20	44.24	33.4	35.3	143	134
SEm±	1.20	1.24	2.82	2.50	0.11	0.13	0.22	0.26	0.25	0.22	2.50	2.11
CD (P=0.05)	3.84	3.97	9.02	8.0	0.35	0.42	0.70	0.83	0.80	0.70	8.0	6.75

Details of treatments are given under Materials and Methods

and 17.9 × 10³ ₹/ha). In 125% of RDF, higher amount of nutrient and yield gain was not sufficient to compensate the cost of cultivation and thus recorded lower net and gross returns over to NES (73.9 and 43.0 × 10³ ₹/ha). NES recorded additional net gain of 8,200 /ha compared to RDF (34.8 × 10³ ₹/ha).

Nutrient uptake and nutrient use efficiency

Tillage practices in maize significantly influenced the uptake of N, P and K in grain and total (grain + straw) at the end of 2 years (Table 4). Decomposition of residue with high availability of nutrient in soil caused higher N, P and K uptake in grain with ZT + R (87.65, 27.25, 32.4 kg/ha) and CT + R (81.35, 25.75 and 31.1kg/ha), followed by CT (73.4, 24.31 and 28.5 kg/ha). In ZT + R, an addition of wheat straw residue @ 16 kg/ha ensured a significant increase of K uptake in grain (21.08%) over CT. Total uptake in maize also followed the same trend. The ZT + R (118, 41.05 and 145 kg/ha) and CT + R (112, 39.30 and 134.5 kg/ha) recorded higher total N, P and K uptake in maize compared to CT (105.5, 36.55 and 126.5 kg/ha). Unavailability of available forms of nutrient in ZT – R resulted in to low uptake of nutrients in grain and total (95.75 and 114.5 kg/ha). The ZT + R recorded (25.3 kg grain/kg N) higher nitrogen-use efficiency (NUE) than to CT (21.5 kg grain/kg N). Retention of residue in ZT and higher grain yield with/unit of applied nutrient enhanced the NUE in maize.

Nutrient management significantly influenced the grain and total uptake of N, P and K in maize during both years (Table 4). Availability of optimized and balanced nutrient from the soil in NES exhibited higher uptake of N, P and K than 125% of RDF. An increase of 21.7, 15.37 and 25.8% was registered with N, P and K in grain with NES over RDF. Similarly, RDF registered a 56.9, 29.02 and 54.1% increase of N, P and K in grain with RDF compared with the control. Optimized nutrient application, addition and decomposition of residues reversed the immobilization effect of nutrients (Pasuquin *et al.,* 2014) over the years, and therefore higher availability of soil nutrient enhanced the nutrient uptake in maize. In NES, an addition of 17 kg N, 24 kg P and 11 kg K/ha compared to RDF practice led to higher nutrient uptake. The NUE was significantly influenced by nutrient-management practices (Table 4). The RDF and NES recorded at par values of NUE, followed by 125% of RDF. In 125% of RDF, higher grain yield with extra amount of nutrient was unable to increase NUE which indicates wastage of nutrient. However, comparable NUE in NES and RDF highlight the efficiency of NES, where lesser amount of nutrient than RDF was found optimum for high grain yield and NUE.

Post fertility status and enzyme activity

After completion of 2-year cropping cycle, a significant amount of nutrient was noticed in the soil (Table 5). Higher residue addition and maize total biomass production showed higher amount of N, P and K in the soil with ZT + R, followed by CT + R and CT practices. This indicates that, addition of residue not only enhanced the nutrient uptake in maize but also left a significant amount of nutrients in soil. An additional (22 kg/ha) N and K (34 kg/ha) was found with ZT + R compared to CT. In addition, a gain of 20, 0.3 and 38 kg/ha of N, P, and K was found with ZT + R over initial soil status. In ZT + R, higher amount of soil microbial biomass C (132 mg/kg) and dehydrogenase activity (16.6 TPF µg/g/h) slowly mineralized nutrients and

Table 5. Effect of tillage and nutrient management on residual soil fertility and microbial activity in plough layer (0–15 cm) after 2 cropping cycles

Treatment	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Soil organic C (%)	Dehydrogenases activity (TPF µg/g/h)	Microbial biomass C (µg/g)
Tillage and crop establishment						
CT	160	12.0	284	0.37	24.2	128
CT + R	174	12.8	308	0.38	25.2	130
ZT –R	152	10.0	274	0.37	20.8	120
ZT + R	182	13.8	318	0.40	26.6	132
SEm±	4.5	0.08	6.05	0.04	1.11	1.25
CD (P=0.05)	14.4	0.26	19.36	NS	3.55	4.0
Nutrient management						
Control	156	10.4	265	0.35	21.7	122
RDF	168	12.2	295	0.39	24.0	128
125% RDF	172	12.8	312	0.39	25.2	130
NES	172	13.2	312	0.39	25.9	130
SEm±	3.8	0.06	4.42	0.02	0.89	0.92
CD (P=0.05)	12.2	0.19	14.14	0.06	2.85	2.94

Details of treatments are given under Materials and Methods

gradually availability of nutrients over the life-cycle of maize main reason behind higher nutrient uptake and residual soil fertility compared to CT + R (130 and 15.2) and CT (128 and 14.2). In case of ZT – R, the lowest activity of soil microbial biomass C and DHA was noticed, and therefore a depletion of 8, 2 and 14 kg/ha of N, P and K was recorded compared to CT.

Available soil N, P and K increased after incorporating crop residues at 3.5 t/ha with ZT + R and CT + R (Table 5). The soil organic C was not influenced by nutrient and tillage practices after 2 years. The build-up of SOC required consistent amount of residues, fertilization and longer time in semi-arid regions. In general, nutrient application enhanced the available N (14.6 kg/ha), P (2.3 kg/ha) and K (41.3 kg/ha) over the control. Initial starter dose was lacking in the control to boost microbial communities, and therefore recorded the lowest amount of soil microbial biomass C (122 mg/kg) and DHA (21.7). No fertilization recorded the lowest amount. In NES, addition of extra amount of 17 kg N and 11 kg K/ha over RDF increased mineralization and availability of nutrients to crop, and thereby left significant amount of soil nutrients (168, 12.2 and 295 kg/ha). In NES, additionally, higher activity of soil microbial biomass C (130) and DHA (25.9) played pivotal role to curtail initial lock-up of nutrient in soil. In NES, production of higher crop biomass and efficient decomposition enhanced the enzymatic activity, as the release of nutrient was sufficient to meet out the food requirement of DHA (Sepat and Rana, 2013). The highest available P (13.2 kg/ha) and available K (312 kg/ha) were recorded in NES in soil owing to direct K supply with carry-over effects and release of K + ion from inorganic soil components (Pasuquin *et al.,* 2014). Addition of 25% extra nutrient dose in 125% of RDF was not advisable, though it left high amount of soil nutrients but it failed to compensate high cost with extra amount of yield. Here, additional dose of inorganic nutrient gave significant amount of soil microbial biomass C (130) and DHA (25.2).

Overall, research highlighted that nutrient management through NES has the potential to enhance crop productiv-

Table 6. Interaction of tillage and nutrient-management options on grain yield (t/ha) of maize during 2018

Nutrient management	Tillage and crop establishment				
	CT	CT + R	ZT–R	ZT + R	Mean
Control	3.15	3.75	3.12	3.58	3.40
RDF	4.72	5.04	4.27	5.15	4.80
125% of RDF	5.19	5.27	4.50	5.66	5.16
NES	4.92	5.59	4.92	6.01	5.36
Mean	4.50	4.91	4.20	5.10	4.68
SEm±	0.13				
CD (P=0.05)	0.38				

Details of treatments are given under Materials and Methods ity, nutrient-use efficiency and soil fertility with minimal harmful effects on environment. Nutrient management through NES follows systematic approach of capturing site-specific information for developing individual farm-based nutrient. So, it is concluded that nutrient management throgh NES is a better option to enhance productivity, profitability and nutrient-use efficiency of maize with retention of residue at 3.5 t/ha in ZT maize under semi-arid regions of India.

Thus, nutrient expert system (NES) in zero-tillage with crop residue at 3.5 t/ha enhances maize yield and net returns. Zero-tillage with NES recorded higher post-soil fertility status with increased activity of dehydrogenase and microbial biomass C in sandy-loam soils.

REFERENCES

Cassida, L.E., Klein, J.R., Santoro, D.A. and Thomas, S. 1964. Soil dehydrogenase activity *Soil Science* **98**(6): 371–376.

FAO. 2022. www.databasefao.org accessed on 12.10.2022

ICAR-IIMR. 2020. *Annual Report 2020*, ICAR-Indian Institute of Maize Research, Punjab Agricultural University Campus, Ludhiana, Punjab

Pampolina, M.F., Witt, C., Pasuquin, J.M., Johnston, A. and Fisher, M.J. 2012. Development approach and evaluation of the nutrient expert software for nutrient management in cereal crops. *Computers and Electronics in Agriculture* **88**: 103–110.

Pasuquin, J.M., Pampolino, M.F., Witt, C., Dobermann, A., Oberthur, T., Fisher, M.J. and Inubushi, K. 2014. Closing yield gaps in Southeast Asia through site-specific nutrient management. *Field Crop Research* **156**: 219–230.

Sepat, S. and Rana, D.S. 2013. Effect of double no-till and permanent raised beds on productivity, profitability and physical properties of soil in maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system *Indian Journal of Agronomy* **58**(4): 469–473.

Sepat, S., Bana, R.S., Meena, S.L. and Rana, D.S. 2019. Assessment of conservation agriculture and intercropping practices for enhanced productivity and profitability in maize (*Zea mays)*. *Indian Journal of Agricultural Sciences* **89**(4): 714–720.

Sepat, S., Sharma, A.R., Kumar, D. and Das, T.K. 2015. Effect of conservation agriculture practices on productivity and sustainability of pigeonpea (*Cajanus cajan*)–wheat (*Triticum aestivum*) cropping system in Indo-Gangetic plains of India. *Indian Journal of Agricultural Sciences* **85**(2): 212–216.

Sepat-Seema, Behera, U.K., Sharma, A.R., Das, T.K. and Bhattacharyya, R. 2014. Productivity, organic carbon and residual soil fertility of pigeonpea–wheat cropping system under varying tillage and residue management. *Proceedings of the National Academy of Sciences*, *India* Section B: *Biological Sciences* 84(**3**): 561–571.

Singh, V., Kaur, R., Singh, B., Brar, B.S. and Kaur, A. 2016. Precision nutrient management: a review. *Indian Journal of Fertilizers* **12**(11): 15–17.

Vance, E.D., Brookes, P.C. and Jenkinson, D.S. 1987. An extraction method for measuring soil microbial biomass C. *Soil Biology and Biochemistry* 19(**6**): 703–707.

Indian Journal of Agronomy **68** (4): 386–391 (December 2023)

Research Paper

Effect of different planting geometry of transplanted pigeonpea (*Cajanus cajan*) as an intercrop in young arecanut (*Areca catechu*) garden at Southern Transitional Zone of Karnataka, India

H.G. SANNATHIMAAPPA[1], A.H. KUMAR NAIK[2] AND MHANUMANTHAPPA[3]

Agricultural and Horticultural Research Station of the University of Agricultural and Horticultural Sciences, Kathalagere, Karnataka 577 219

Received: April 2022; Revised accepted: November 2023

ABSTRACT

A field experiment was conducted during 2017–18, 2018–19 and 2019–20, to study the influence of planting methods on growth and productivity of pigeonpea [*Cajanus cajan* (L.) Millsp.]. The experiment was laid out in randomized complete block design with 8 treatment combinations and replicated thrice. Pooled data indicated that transplanted pigeonpea at 60 cm × 30 cm geometry gave significantly higher pigeonpea seed and stalk yield (2,353 and 6,533 kg/ha respectively), and it was followed by 60 cm × 60 cm spacing (2,072 and 5,852 kg/ha respectively). The above-mentioned treatments also recorded significantly higher total uptake of nitrogen (129.18 and 123.39 kg/ha respectively), phosphorus (36.84 and 32.40 kg/ha respectively) and potassium (62.57 and 57.58 kg/ha respectively), whereas, higher available nitrogen, phosphorus and potassium (246.64, 35.87 and 155.65 kg/ha respectively) were recorded in 180 cm × 30 cm. Further higher nitrogen, phosphorus and potassium content in arecanut leaf (*Areca catechu* L.) was observed in 60 cm × 60 cm (1.72 %), 120 cm × 30 cm (0.260 and 1.20 %) as compared to other planting geometry in young arecanut garden.

Key words: Nutrient, Pigeonpea, Transplanting, Yield, Uptake

Current climatic condition in agriculture is unpredictable for stable crop production and becoming uneconomical to the farmers in dryland areas. Appropriate cropping systems besides meeting the varied requirements of farmer, provide stability in rainfed agriculture and improve the total productivity through better utilization of natural resource. In Southern Transitional Zone of Karnataka, the fields which are used for the cultivation of rice (*Oryza sativa* L.) before are converted it into arecanut (*Areca catechu* L.) estate. Those fields have soft soil with good fertility and also continues water supply to the land, which made the best location to grow arecanut. Application of silt is most common in young arecanut gardens, which may affect the native soil fertility. Inclusion of legumes in arecanut gardens leads to increase in the soil fertility through biological fixation of atmospheric dinitrogen (N_2) by legume-rhizobial symbioses, and the buildup of slowly weathered nutrients in plant biomass. On account of biological nitrogen fixation, addition of considerable amount of organic matter through root biomass and leaf fall, deep root-systems, mobilization of nutrients, protection of soil against erosion and improving microbial biomass, they keep soil productive and alive by bringing qualitative changes in physical, chemical and biological properties (Bansal, 2011).

Pigeonpea [*Cajanus cajana* (L.) Millsp.] is one of the major grain legume crops of tropical and subtropical regions and it is grown predominantly under rainfed conditions. India accounts for 90% of world's pigeonpea growing area and 85% of world's production of pigeonpea. As a soil ameliorant, pigeonpea is known to provide several benefits to the soil in which it is cultivated (Murali *et al.,* 2014). When pigeonpea is grown as a sole crop, it is relatively inefficient because of its slow initial growth rate and low harvest index (Willey *et al.,* 1980). Moreover, terminal moisture stress during reproductive stage further declines pigeonpea productivity. In order to ensure timely sowing due to the late onset of monsoon and to overcome the competitive suppression of transplanting pigeonpea seedlings may be one of the agronomic measures to overcome

[1]**Corresponding author's Email:** sthgagron@gmail.com
[1]Professor of Agronomy, AHRS, Kathalagere, Davanagere Dist., Karnataka 577 219; [2]Junior Scientist (Agronomy), AICRP on Groundnut, ZAHRS, Babbur Farm, Hiriyur, Chitradurga Dist., Karnataka 577 598; [3]Vice Chancellor, University of Agricultural Sciences, Raichur, Karnataka 584 104

delayed sowing. This technique involves raising of seedlings in the polythene bags in nursery and transplanting these seedlings in the main field after certain age. As established seedlings, these-pick-up-growth quickly under field condition and can be more competitive. Hence a study was carried out to find out the effect of different planting geometry of transplanted pigeonpea as an intercrop in young arecanut garden on growth and productivity of pigeonpea.

MATERIALS AND METHODS

The experiment was conducted at Agricultural and Horticultural Research Station, Kathalagere, University of Agricultural and Horticultural Research Station, Shivamogga, Karnataka, India, during under rainfed condition during rainy (*kharif*) and winter (*rabi*) seasons (June–November) of 2017–18, 2018–19 and 2019–20. During the crop growth period, a total rainfall of 643.1 and 708 mm was received during both the years, which was optimum for good growth and higher yield. The soil of the experimental site is Typic Hapstaurt with pH of 6.8 and electrical conductivity of 0.18 dS/m. The soil is medium in organic carbon (0.61%) and low in available nitrogen (358.6 kg/ha) and medium in available P (22.5 kg/ha) and available K (237 kg/ha). The experiment was laid out in a randomized complete-block design, involving 8 treatments in 3 replications. The details of the treatments included transplanted pigeonpea at spacing of 60 cm × 30 cm, 60 cm × 60 cm, 120 cm × 30 cm, 120 cm × 60 cm, 150 cm × 30 cm, 150 cm × 60 cm, 180 cm × 30 cm and 180 cm × 60 cm. Indeterminate semi spreading, green podding, bold seeded pigeonpea variety 'BRG 2' (175–185 days maturity period) was selected. In order to raise seedlings of pigeonpea healthy, bold treated seeds were sown in black polythene bags (size 15 cm × 6 cm) filled with soil and vermicompost in the last week of May. Regular watering was done to raise the seedlings for a period of 4 weeks in the nursery. Transplanting of pigeonpea seedlings, direct sowing of pigeonpea and intercrops seeds were done at the onset of the rains during the last week of June. Marking with the help of marker was done as per the row and intra-row spacing of respective treatments and at each hill small pits were opened with the help of pickaxe to a depth of 15–20 cm and then pigeonpea seedlings were transplanted after removing the polythene cover without disturbing the soil at the root zone of the pigeonpea seedling. The recommended quantity of FYM (6 t/ha) was applied 2 weeks before sowing and transplanting of the crop. The entire quantity of recommended dose of fertilizer for pigeonpea (25 : 50 : 0 kg N : P_2O_5 : K_2O/ha) was applied in the form of urea, diammonium phosphate (DAP) and muriate of potash were applied at the time of sowing and transplanting as basal dose at 5 cm deep and 5 cm away from the seeds and seedlings, then covered with soil. Pigeonpea crop was harvested and threshed from the net plot area and produce was dried and recorded as net plot yield from which yield/ha was computed. Composite soil samples were used to assess soil-nutrient status. Fisher's method of analysis of variance was used for analysis and interpretation of the data (Panse and Sukhatme, 1967). The level of significance used in F and t tests was P=0.05. Critical differences were calculated wherever F tests were significant.

RESULTS AND DISCUSSION

Yield parameters

Pooled data of transplanted pigeonpea with a planting geometry of 180 cm × 30 cm showed significantly higher yield parameters, viz. pods/plant and pod weight/plant (883 and 580 g/plant respectively), followed by 60 cm × 30 cm treatment (Table 1) This may be owing to wider availability of spacing, more availability of light and moisture, which made the plant to grow vigorously and this might have experienced less competition than narrow spacings. Pod weight/plant is also one of the important yield attributing traits. Significant differences in seed yield of pigeonpea was observed with closer spacing of 60 cm × 30 cm over other spacings, because of more plant population per unit area These results are in accordance with the findings of Pavan *et al.* (2009) and Mula *et al.* (2011).

Seed and stalk yield

The trend of pooled data with respect to seed and stalk yield followed similar pattern as that of individual years. The seed and stalk yield differed significantly due to different planting geometry treatments during individual years and in pooled analysis (Table 1). Higher seed and stalk yield was obtained with the spacing of 60 cm × 30 cm (2,353 and 6,533 kg/ha, respectively) and 60 cm × 60 cm (2,072 and 5,852 kg/ha respectively). This may be attributed to more plant population per unit area obtained higher economical and biological yield owing to better plant development, resulting in more uniform distribution of plants over cropped area coupled with greater light interception, moisture utilization, nutrient and solar energy availability under lower degree of inter-and intra-plant competitions. These favourable conditions for growth caused significantly higher values of yield components under. However, these higher values of yield components could not compensate for loss in yield due to lower plant population. Hence, wider spacing recorded significantly lower yield than closer spacing. Similar reductions in yield under wider spacing was reported by Shaik Mohammed (1997) and Parameswari *et al.* (2003) under winter season situation. The higher stalk yield with the higher plant population was owing to more plants/unit area. These results are in

Table 1. Effect of different planting density of pigeonpea on yield parameters and yield under young arecanut garden

Treatment	Pods/plant			Pod weight/plant (g)			Seed yield (kg/ha)			Stalk yield (kg/ha)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1, 60 cm × 30 cm	656	806	731	431	506	469	2234	2471	2353	6147	6919	6533
T_2, 60 cm × 60 cm	615	702	659	416	487	452	1848	2296	2072	4961	6742	5852
T_3, 120 cm × 30 cm	583	618	601	391	453	422	1914	2156	2035	4879	6534	5707
T_4, 120 cm × 60 cm	527	545	536	376	441	409	1821	2050	1936	4925	6218	5572
T_5, 150 cm × 30 cm	491	704	598	357	419	388	1784	2021	1903	5081	5926	5504
T_6, 150 cm × 60 cm	468	575	522	338	392	365	1658	1975	1817	5234	5796	5515
T_7, 180 cm × 30 cm	769	996	883	541	618	580	1605	1918	1762	5148	5608	5378
T_8, 180 cm × 60 cm	628	751	690	424	485	455	1594	1870	1732	4985	5234	5110
SEm±	14	21	26	14	26	21	68	89	70	65	173	164
CD (P=0.05)	43	61	78	41	77	62	201	264	211	193	514	486

conformity with the findings of Legha and Dhingra (1992) and Mohite *et al.* (1993), who observed higher stalk yield with closer plant geometry. Nagamani *et al.* (1995) and Pavan *et al.* (2009) also recorded higher stalk yield with increase in number of plants per hectare. Further, the higher stalk yield with the higher plant population was owing to more number of plants/unit area and greater retention of dry-matter in stem. Over and above that, gap-filling through transplanted pigeonpea had some potential to give higher yield, as it could enable timely planting and maintenance of adequate plant population in pigeonpea, the twin issues related to realization of higher crop productivity in pigeonpea.

Nutrient uptake

Significantly higher total uptake of nitrogen (129.18 and 123.39 kg/ha respectively), phosphorus (36.84 and 32.40 kg/ha, respectively) and potassium (62.57 and 57.58 kg/ha respectively) were recorded under 60 cm × 30 cm and 60 cm and 60 cm planting geometry treatments respectively (Table 2). Nutrient uptake was also influenced by intercultural operations carried out at optimum time. Further application of inorganic nutrients possibly increased the concentration of N, P and K ions of soil solution and ultimately affected the formation of more nodules, vigorous root development, better N fixation and better development of plant growth leading to higher photosynthetic activity and translocation of photosynthates to the sink which in turn resulted in better uptake of nutrients (Kumar and Singh, 2011).

Availability of nutrients

Significantly higher available nitrogen, phosphorus and potassium (246.64, 35.87 and 155.65 kg/ha respectively) were recorded in 180 cm × 30 cm planting geometry, followed by 150 cm × 60 cm (245.34 kg/ha of nitrogen), 180 cm × 30 cm (32.39 kg/ha of phosphorus) and 150 cm × 60 cm (151.46 kg/ha of potassium) (Table 3). Higher availability of N, P and K over other spacings was because of inefficient utilization of nutrients from the soil by lesser plant population per unit area. There was no interaction between availability of nutrients and plant densities for any of the sites evaluated. This finding indicated that, increasing availability of nutrients in fields with reduced plant population, or increasing plant population but reducing N rates is not feasible for improving pigeonpea production. This trend contradicts Dong *et al*. (2012), who found that cotton (*Gossypium* sp.) yield could be maximized using low plant density at a high nutrients application rate or high plant density at any nutrients rate. Considering that cultivation of transplanted pigeonpea is expanding in the tropics with limited scientific validation of best management practices.

Table 2. Effect of different planting density of pigeonpea on total nutrient uptake under young arecanut garden

Treatment	Total nutrient uptake (kg/ha)								
	Nitrogen			Phosphorus			Potassium		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1, 60 cm × 30 cm	121.64	136.72	129.18	34.41	39.26	36.84	58.72	66.42	62.57
T_2, 60 cm × 60 cm	114.57	132.21	123.39	29.32	35.47	32.40	55.28	59.88	57.58
T_3, 120 cm × 30 cm	108.14	120.53	114.34	26.29	29.81	28.05	45.73	48.59	47.16
T_4, 120 cm × 60 cm	118.27	127.36	122.82	29.04	34.11	31.58	49.26	54.18	51.72
T_5, 150 cm × 30 cm	111.85	122.71	117.28	26.28	30.51	28.40	46.16	50.83	48.50
T_6, 150 cm × 60 cm	104.56	113.69	109.13	24.19	28.15	26.17	41.26	45.68	43.47
T_7, 180 cm × 30 cm	116.92	127.51	122.22	28.37	31.49	29.93	47.22	51.86	49.54
T_8, 180 cm × 60 cm	92.83	107.36	100.10	25.93	28.74	27.34	43.13	46.95	45.04
SEm±	5.65	5.84	6.84	1.23	1.31	1.63	1.99	2.02	2.06
CD (P=0.05)	16.80	17.35	20.32	3.66	3.90	4.84	5.92	6.01	6.14

Table 3. Effect of different planting density of pigeonpea on available nutrient status (kg/ha) of the soil under younger arecanut garden

Treatment	Available nutrient status (kg/ha)								
	Nitrogen			Phosphorus			Potassium		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1, 60 cm × 30 cm	228.81	236.29	232.55	21.32	24.58	22.95	132.42	142.69	137.56
T_2, 60 cm × 60 cm	231.66	240.82	236.24	23.71	28.45	26.08	135.39	146.25	140.82
T_3, 120 cm × 30 cm	236.74	244.38	240.56	26.46	30.17	28.32	137.52	145.71	141.62
T_4, 120 cm × 60 cm	229.41	236.16	232.79	23.82	26.49	25.16	135.78	142.36	139.07
T_5, 150 cm × 30 cm	235.26	248.36	241.81	26.64	29.28	27.96	139.27	151.80	145.54
T_6, 150 cm × 60 cm	238.92	251.75	245.34	32.39	36.07	34.23	143.94	155.06	149.50
T_7, 180 cm × 30 cm	240.08	253.19	246.64	32.87	38.16	35.52	148.02	163.28	155.65
T_8, 180 cm × 60 cm	236.58	249.70	243.14	30.26	38.53	34.40	143.48	159.44	151.46
SEm±	2.34	3.17	2.68	2.58	2.97	3.03	2.06	3.33	2.37
CD (P=0.05)	6.97	9.41	7.97	7.68	8.82	9.01	6.14	8.96	7.04

Availability of nutrients at different depths during 2019 and 2020

Available nutrient status at 0–30 cm depth: The data revealed (Table 4) that, significant influence of treatments on availability of nutrients which was higher in 120 cm × 30 cm (295.34 kg/ha of nitrogen), 120 cm × 60 cm (49.79 and 303.41 kg/ha of phosphorus and potassium respectively), followed 60 cm × 60 cm (274.59 kg/ha of nitrogen), 150 × 60 cm (45.03 kg/ha of phosphorus) and 120 × 30 cm (287.55 kg/ha of potassium) as compared to rest of the treatments. The treatments with application of chemical fertilizers resulted in excess deposition of available K in both surface and subsurface zone. The improvement in soil-N status subsequent to the legumes due to the biological nitrogen fixation. Further, it is evident that there is a variation among the legumes in accumulation of N and its availability to the intercrops crops can be seen among the legume crops. These results are in accordance with the findings of Lal and Singh (2007) and Sharma and Behera (2009) also reported that, only 30% of N and 66% of P from legume residues is likely to be used by the first crop, the remaining maybe available to the perennial intercrop and to a little extent to the subsequent crops raised on the same land. Further, high lignin in pigeonpea or high polyphenol in hairy indigo were expected to influence the rates of N mineralization. In particular, roots of pigeonpea residues showed surprisingly fast decomposition and net N release patterns mainly due to their high N-concentration (Sakala *et al*., 2000).

Available nutrient status at 30–60 cm depth

Significantly higher availability of nutrients at 30 cm–60 cm depth was analyzed in 120 cm × 30 cm (242.68 kg/ha of nitrogen), 120 cm × 60 cm (36.79 kg/ha of phosphorus) and 150 cm × 60 cm (229.53 kg/ha of potassium) and it was followed by 150 cm × 60 cm (235.63 and 31.48 kg/ha of nitrogen and phosphorus respectively) and rest of the treatments were at par with each other (Table 5). As compared to 0–30 cm depth, the subsurface soils contained comparatively less available N, P and K content. Application of inorganic fertilizer coupled with irrigation might be the reason; it leads to the binding of cations and organic

Table 4. Available nutrient status (0–30 cm depth) of the soil during growth period of arecanut

Treatment	Available nutrient status (kg/ha)								
	Nitrogen			Phosphorus			Potassium		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1, 60 cm × 30 cm	237.56	249.02	243.29	24.56	22.43	23.49	229.68	236.21	232.95
T_2, 60 cm × 60 cm	269.37	279.80	274.59	31.29	30.39	30.84	244.93	243.13	244.03
T_3, 120 cm × 30 cm	290.12	300.55	295.34	33.87	34.99	34.43	288.89	286.20	287.55
T_4, 120 cm × 60 cm	248.74	252.68	250.71	49.12	50.47	49.79	301.45	305.37	303.41
T_5, 150 cm × 30 cm	259.06	263.90	261.48	43.18	44.63	43.91	269.60	270.94	270.27
T_6, 150 cm × 60 cm	269.37	274.96	272.17	44.86	45.19	45.03	282.61	289.84	286.23
T_7, 180 cm × 30 cm	248.74	259.06	253.90	35.75	34.77	35.26	219.81	226.12	222.97
T_8, 180 cm × 60 cm	241.59	247.96	244.78	34.21	36.48	35.35	207.62	212.28	209.95
SEm±	4.13	5.08	4.27	3.36	4.22	3.72	15.20	16.01	16.60
CD (P=0.05)	12.28	15.09	11.48	10.94	12.53	11.05	45.13	47.54	49.28

Table 5. Available nutrient status (30–60 cm depth) of the soil during growth period of arecanut

Treatment	Available nutrient status (kg/ha)								
	Nitrogen			Phosphorus			Potassium		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1, 60 cm × 30 cm	197.66	214.17	205.92	15.35	14.70	15.02	176.94	169.01	172.97
T_2, 60 cm × 60 cm	239.80	198.16	218.98	22.12	24.37	23.25	218.66	185.86	202.26
T_3, 120 cm × 30 cm	245.55	239.80	242.68	27.20	31.15	29.17	200.41	186.65	193.53
T_4, 120 cm × 60 cm	219.26	250.29	234.78	35.77	37.80	36.79	221.18	227.05	224.11
T_5, 150 cm × 30 cm	222.08	230.09	226.09	28.10	30.24	29.17	214.86	218.02	216.44
T_6, 150 cm × 60 cm	229.42	241.83	235.63	29.00	31.48	30.24	233.82	225.24	229.53
T_7, 180 cm × 30 cm	208.54	243.97	226.26	23.81	25.50	24.66	195.90	199.40	197.65
T_8, 180 cm × 60 cm	201.28	222.68	211.98	16.38	19.93	18.16	186.58	199.03	192.81
SEm±	8.11	9.75	8.44	3.66	3.91	4.70	10.18	11.30	9.96
CD (P=0.05)	24.08	28.96	25.06	10.89	11.61	13.96	30.53	33.57	29.59

acids resulting in leaching of soluble solids, reduces the nutrient-retention capacity of the soil resulted lesser availability of nutrients under subsurface zone of soil in the above treatments. Compounds such as polyphenols in decomposing residues, could decrease the rate of litter decomposition and N mineralization by inhibiting the enzyme activity of the decomposer community or complexation of proteins at subsurface layer of the soil (Handayanto *et al.,* 1997). Increased root proliferation in arecanut due to intercropping would increase organic matter content in soil. It was observed that, intercropping legumes increased the content of available nitrogen and other nutrients in arecanut plantation. Several advantages like fixation of N, recycling of nutrients in the soil profile, prevention of soil erosion and improved soil fertility are reported owing to intercropping with leguminous green-manure crops or cover crops in arecanut. It was further noticed that, intercropping with legumes in arecanut gardens could add on an average 10 kg green manure/palm which could meet 69 to 89% of N requirement, 28 to 43% P and 29–38% of K. Fungal and bacterial population was relatively more under intercropping situations than in sole crop of arecanut (Sujatha and Bhat, 2015).

Nutrient content (%) in arecanut leaf for two consecutive years

Significantly higher nutrients content (Table 6) was observed with spacing of 60 cm × 60 cm and 120 cm × 30 cm (1.72 and 1.71% of nitrogen respectively), 120 cm × 30 cm and 150 cm × 60 cm (0.260 and 0.250% of phosphorus respectively) and 120 cm × 30 cm and 120 cm × 60 cm (1.20 and 1.18% of potassium respectively). Higher dry-matter accumulation in different plant parts (leaf, stem and reproductive parts) with wider spacings resulted in higher total dry-matter/plant, which may increases availability of nutrients to the arecanut. Inclusion of legumes in the arecanut plantations add sufficient amount of organic matter to the soil and solubilize plant nutrients and improve physical conditions of the soil by accelerating porosity, aeration and water-holding capacity. It is also well documented fact that, legume residues with inorganic fertilizers in the soil not only acts as storehouse of macro- and micronutrients but also favourably affect physical and chemical characteristics of soil and plant (Bhriguvanshi, 1988).

Thus it may be concluded that higher seed and stalk yield was obtained with the spacing of 60 cm × 30 cm (2,353 and 6,533 kg/ha respectively) and 60 cm × 60 cm

Table 6. Nitrogen, phosphorus and potassium content (%) in arecanut leaf across, the years

Treatments	Nitrogen			Phosphorus			Potassium		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1, 60 cm × 30 cm	1.32	1.34	1.33	0.17	0.19	0.180	1.11	1.13	1.12
T_2, 60 cm × 60 cm	1.70	1.74	1.72	0.20	0.21	0.205	1.12	1.15	1.14
T_3, 120 cm × 30 cm	1.72	1.70	1.71	0.25	0.27	0.260	1.19	1.21	1.20
T_4, 120 cm × 60 cm	1.46	1.51	1.49	0.23	0.26	0.245	1.17	1.19	1.18
T_5, 150 cm × 30 cm	1.63	1.65	1.64	0.21	0.22	0.215	1.13	1.14	1.14
T_6, 150 cm × 60 cm	1.55	1.59	1.57	0.24	0.26	0.250	1.10	1.12	1.11
T_7, 180 cm × 30 cm	1.50	1.56	1.53	0.21	0.23	0.220	1.14	1.15	1.15
T_8, 180 cm × 60 cm	1.55	1.62	1.59	0.20	0.21	0.205	1.16	1.18	1.17
SEm±	0.10	0.11	0.11	0.016	0.02	0.013	0.016	0.02	0.016
CD (P=0.05)	0.30	0.32	0.33	0.05	0.06	0.04	0.05	0.06	0.05

(2,072 and 5,852 kg/ha respectively). Significantly higher nitrogen (1.72%), phosphorus (0.260%) and potassium (1.20%) content in arecanut leaves was observed with spacing of 60 cm × 60 cm and 120 cm × 30 cm respectively. Higher available nitrogen, phosphorus and potassium (246.64, 35.87 and 155.65 kg/ha respectively) were recorded in 180 cm × 30 cm planting geometry. Inclusion of legumes as intercrop in arecanut acts as an supplemental addition of organics improving the growth of arecanut substantially increased the fertility status of the soil.

REFERENCES

Bansal, Amrit Kaur. 2011. Effect of organic, inorganic and bio-fertilizer in soil fertility under double cropping system in rainfed red soils. *Indian Journal Agronomy* **45**(2): 242–247.

Bhriguvanshi, S.R. 1988. Long term effect of high doses of farm yard manure on soil properties and crop yield. *Journal of Indian Society of Soil Science* **36**: 787–790.

Dong, H., Li, W., Enejia, A.E. and Zhang, D. 2012. Nitrogen rate and plant density effects on yield and late-season leaf senescence of cotton raised on a saline field. *Field Crops Research* **126**: 137–144.

Handayanto E., Giller, K.R. and Cadisch, G. 1997. Regulating N release from legume tree prunings by mixing residues of different quality. *Soil Biology and Biochemistry* **29**: 1,417–1,426.

Kumar, S. and Singh, B.P. 2011. Response of pigeonpea genotypes to level of phosphorus and sulphur. *Annals of Plant and Soil Research* **13**(1): 53–55.

Lal, T. and Singh, D. 2007. Effect of preceding crops and nitrogen levels on drymatter accumulation and nitrogen use efficiency in wheat. *Journal of Research, Punjab Agricultural University, Ludhiana* **44**(1): 1–5.

Legha, P.K. and Dhingra, K.K. 1992. Phenology and yield potential of arhar cv. T-21 as influenced by planting pattern and time of sowing. *Crop Research* **5**(1): 157–159.

Mohite, A.A., Pol, P.S. and Umarani, N.K. 1993. Response of rainy season pigeonpea to spacing and fertilizer. *Indian Journal of Agronomy* **38**(2): 314–315.

Mula, M.G., Saxena, K.B., Kumar, R.V. and Rathore, A. 2011. Influence of spacing and irrigation on the seed yield of a CMS line 'ICPA 2043' of hybrid pigeonpea. *Journal of Food legumes* **24**(3): 202–206.

Murali, K., Sheshadri, T. and Byregowda, M. 2014. Effect of pigeonpea transplanting on growth, yield and economics in sole and finger millet intercropping system under late sown conditions. *Journal of Food legumes* **27**: 28–31.

Nagamani, G., Rao. P.G. and Rao, D.S.K. 1995. Response of pigeonpea cultivars to plant densities in post-rainy season. *Journal of Maharashtra Agricultural Universities* **20**(1): 125–126.

Panse, V.G. and Sukhatme, P.V. 1967. Statistical Methods for Agricultural Workers pp. 167–174. Indian council of Agricultural Research, New Delhi.

Parameswari, K., Vanagamudi, K. and Kavitha, S. 2003. Effect of spacing on hybrid seed yield of pigeonpea hybrid CoPH-2. *Madras Agricultural Journal* **90**(10–12): 691–696.

Pavan, A.S, Nagalikar, V.P, Pujari, B.T. and Halepyati, A.S. 2009. Influence of planting geometry on the growth characters, seed yield and economics of transplanted pigeonpea. *Karnataka Journal of Agricultural Sciences* **24**(3): 390–392.

Sakala, W.D., Cadisch, G. and Giller, K.E. 2000. Interactions between residues of maize and pigeonpea and mineral N fertilizers during decomposition and N mineralization. *Soil Biology and Biochemistry* **32**: 699–706

Shaik, Mohammed. 1997. Relative performance of pigeonpea genotypes and their response to row spacing. *Indian Journal Pulses Research* **10**(1): 14–18.

Sharma, A.R. and Behera, U.K. 2009. Nitrogen contribution through sesbania green manure and dual-purpose legumes in maize–wheat cropping system: Agronomic and economic considerations. *Plant and Soil* **325**: 289–304.

Sharma, N., Murty, N.S., Mall, P. and Bhardwaj, S.B. 2018. Ananalysis on the yield and yield contributing characters of ricein tarai region of Uttarakhand. *International Journal of Chemical Study* **6**(3): 42–47.

Sujatha, S. and Bhat, Ravi. 2015. Resource use and benefits of mixed farming approach in arecanut ecosystem in India. *Agricultural Systems* **141**: 126–137.

Willey R.W., Rao, M.R. and Natarajn, M. 1980. Traditional cropping systems with pigeonpea and their improvement. (In) *Proceedings of International Workshop on Pigeonpea*, held on 15 December 1980 at the International Crops Research institute3 for the Semi-Arid Tropics, Patancheru, Hyderabad, India, pp. 11–25.

Indian Journal of Agronomy **68** (4): 392–397 (December 2023)

Research Paper

Effect of varietal selection and nutrient management on productivity, soil fertility and economics of summer groundnut (*Arachis hypogaea*)

RAJIB KUNDU[1], RATNESWAR PODDAR[2*], ARUP SEN[3], ARINDAM SARKAR[4] AND DIBAKAR GHOSH[5]

All India Coordinated Research project on Groundnut, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741 235

Received: May 2022; Revised accepted: November 2023

ABSTRACT

A field experiment was conducted at research farm of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, during 3 consecutive summer seasons of 2017, 2018 and 2019, to find out the influence of varietal differences and nutrient-management practices on crop productivity, soil fertility and economics in groundnut (*Arachis hypogaea* L.). The experiment was laid out in a split-plot design with 3 replications. Higher crop growth and yield were recorded under variety 'TAG 24'; and 125% recommended dose of fertilizer (RDF) with *Rhizobium* inoculation resulted higher growth, yield attributes and yield of groundnut followed by 100% RDF + *Rhizobium* inoculation. The nutrient (N, P and K) availability in soil after harvesting was also higher under 'TAG 24' variety with 125% RDF + *Rhizobium*. However, interaction effect of crop variety and fertilizer treatment was found insignificant. The pooled analysis of economics revealed that, higher benefit: cost ratio (2.73) was obtained under 'TAG 24' in combination with 100% RDF+ *Rhizobium*.

Key words: Economics, Fertilizer, Groundnut, *Rhizobium*, Soil fertility, Yield

Oilseeds are considered important commercial crops in our country and India ranks second in oilseed production globally. Oilseeds occupy an important part of our daily dietary nutrition. They are rich in proteins, carbohydrates, lipids, minerals and oils. Despite having large area under cultivation, India imports considerable amount of edible oils. Groundnut (*Arachis hypogaea* L.), among the different oilseeds contributes about 15% of the total vegetable oil production in India (Gharge *et al*., 2017). Recently, with expansion of food and confectionery industries, the demand of groundnut is also increasing. However, groundnut production/unit area is quite low in India

Though area and production of groundnut is higher in the rainy (*kharif*) season, productivity is quite higher in summer season, primarily owing to better utilization of fertilizer and improved cultivation and management practices particularly in marginal and sub-marginal lands where deficiency of different nutrient is predominant (Singh *et al*., 2020); and uncertain and irregular rainfall and prolonged dry spells during the growth period of groundnut during *kharif* and post-*kharif* season (Reddy *et al*., 2023). However, continuous cropping without proper nutrient management practice has led to deterioration of soil fertility, stagnation or even decline in crop production and productivity (Sathiya *et al*., 2020). Use of high analysis chemical fertilizers indiscriminately triggers the deficiency of other nutrients (Singh *et al*., 2020). However, integration of chemical, organic and biological sources of nutrients is the most efficient way to supply plant nutrients for sustained crop production and soil fertility (Dasgupta *et al*., 2017; Haldar *et al*., 2019). Biofertilizers play an important role in crop production, enhancing nutrient-supply capacity of the system (Sen *et al*., 2021; Singh *et al*., 2021). Studies have reported increased oil and protein content with biofertilizer application (Kundu *et al*., 2023).

Development of improved variety may increase the crop production and acts as an alternative method for sustainable crop production (Meena and Yadav, 2015). However, for higher crop production huge amount of inorganic fertilizers is required, which are very costly. Therefore, it is necessary to find out the performance of different groundnut varieties under integrated nutrient management. The main objective of the present study was to evaluate response of 2 groundnut varieties under various levels of nutrient

[2]**Corresponding author's Email:** rpoddar.bckv@rediffmail.com
[1]Assistant Professor, AICRP on Groundnut, [2]Assistant Professor (Agronomy), AICRP on Irrigation Water Management; [3]Assistant Professor, Department of Agricultural Chemistry and Soil Science, [4]Assistant Professor, Regional Research Station (Red and Laterite Zone), Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal 741 235; [5]Scientist, ICAR-Indian Institute of Water Management, Chandrasekharpur, Bhubaneswar, Odisha 751 023

management during the summer season. We hypothesized that higher level of fertilizers with biofertilizer would enhance crop nutrient uptake, improve growth and yield of the crop.

MATERIALS AND METHODS

The field experiment was conducted during 3 consecutive summer seasons of 2017, 2018 and 2019 at research farm of the Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal (22°97′ N, 88°43' E, 9.75 above mean sea-level), India. The site receives an average rainfall of 1,450–1,650 mm/annum. The South-West monsoon (June to September months) contributes more than 75% of the annual rainfall. The mean monthly temperature varies between 26.0 and 38.8°C in summer and 10.6 and 25.9°C in winter. The soils of the experimental site were sandy clay loam (sand 64.7%, silt 12.5% and clay 22.8%), with a neutral reaction *p*H of 7.3 and an electrical conductivity of 0.3 ds/m. It contained 0.6% organic carbon (OC), 152.8 kg available nitrogen (N)/ha, 24.3 kg available P_2O_5/ha and 129.2 kg available K_2O/ha. The field was medium in slope having well-irrigation facility.

The experiment was laid out in a split-plot design and replicated thrice. The mainplot consisted of 2 popular and well-established variety of the region, viz. 'TAG 24' (V_1) and 'TG 51' (V_2) and the subplot contained 6 different level of fertilizer , viz. 75% recommended dose of fertilizer (RDF) (F_1), 100% RDF (F_2),125% RDF (F_3), 75% RDF + *Rhizobium*-seed treatment (F_4), 100% RDF + *Rhizobium*-seed treatment (F_5) and 125% RDF + *Rhizobium*-seed treatment (F_6). Recommended dose of fertilizer was applied at the rate of 20 kg N/ha, 60 kg P_2O_5/ha and 40 kg K_2O/ha in the form of urea, single superphosphate and muriate of potash respectively. Groundnut seeds were inoculated with *Rhizobium* inoculant (*Bradyrhizobium arachidis* @ 20 g/kg seed) before sowing in the field. Seeds were sown during the second fortnight of February of each experimental year at a depth of 3–4 cm with row-to-row spacing of 30 cm and seed-to-seed spacing of 10 cm. Other agronomic practices were followed as per the recommended package of practices for groundnut cultivation specified for this agro-ecological zone.

Five plants from each plot were selected randomly for measurement of growth and physiological parameters. Plant height, dry-matter accumulation (g/m^2), number of pods/plant, shelling (%), sound mature kernel percentage (SMK%), 100-kernel weight (g) were measured following standard methods. Crop harvested from the net plot were taken to threshing floor, dried, threshed and weighed to obtain the pod and kernel yield. The harvest index (HI) was calculated as per Donald (1963).

Composite surface soil samples (depth 0-15 cm) were collected each year after harvesting of the crop; dried at 60°C for 72 hours and ground in agate mortar before any chemical analysis. Soil-available N was determined following hot alkaline $KMnO_4$ method (Subbiah and Asija, 1956). Soil phosphorus was measured by Olsen's method (Olsen *et al*., 1954). Flame photometer was used to measure available K in soil (Jackson, 1973).

All the variables were subjected to ANOVA analysis meant for split-plot design (Gomez and Gomez, 1984) in SAS (v.9.3). The standard error of mean (SEm±) and the value of least significant difference (LSD) at 5% level of significance were indicated in the tables to compare the difference between the mean values.

RESULTS AND DISCUSSION

Growth parameters

No significant difference was found between the 2 varieties for the growth parameters (Table 1). Plant height and dry-matter accumulation were also comparable under both the varieties. Higher plant height was observed under the variety 'TAG 24' (43 cm), whereas variety 'TG 51' recorded greater dry-matter accumulation (362.3 g/m^2).

Increasing level of fertilizers resulted higher plant height and dry-matter accumulation in plants. The treatment with 125% RDF + *Rhizobium* inoculation recorded maximum plant height (44.1 cm) and dry-matter accumulation (384.7 g/m^2) during harvesting. However, *Rhizobium* inoculation did not change plant growth significantly at comparable level of nutrient addition.

Yield parameters

Yield attributes like number of pods/plant, SMK (%), pod yield, haulm yield, kernel yield and harvest index (HI) showed no significant difference between 2 varieties except shelling percentage (Table 1). Under the main plot treatment, 'TG 51' groundnut recorded higher pod number/plant (24.6), shelling% (70.3), SMK% (85.4), 100-kernel weight (44.8 g), pod yield (2,860 kg/ha), haulm yield (3,623 kg/ha) and kernel yield (2,012 kg/ha) than the other variety. However, higher HI was found under variety 'TAG 24' (44.8%) than variety 'TG 51' (44.1%).

Different level of fertilizers resulted on considerable influence on yield parameters (Table 1). An increase in pod number/plant, SMK%, 100-kernel weight, pod yield, haulm yield, and kernel yield was observed when fertilizer dose was higher. However, inoculation with *Rhizobium* did not influence the yield attributes significantly at similar level of nutrient addition. The treatment with 125% RDF and *Rhizobium* inoculation showed the highest number of pods/plant (27), SMK (86.3%), 100 kernel weight (45.6 g), pod yield (3,059 kg/ha), haulm yield (3,847 kg/ha), kernel yield (2,152 kg/ha) and HI (44.3%). In terms of yield

Table 1. Effect of variety and nutrient management on the crop characteristics of groundnut (pooled)

	Plant height (cm) at harvest	Dry-matter production (g/m^2) 45 DAE	60 DAE	75 DAE	At harvest	Pods/ plant	Shelling (%)	SMK (%)	100-KW (g)	Yield (kg/ha) Pod	Haulm	Kernel	Harvest Index (%)
Varieties													
'TAG 24'	43.0	60.9	95.5	223.3	357.8	23.4	69.7	84.2	44.2	2,827	3,578	1,972	44.8
'TG 51'	42.6	62.2	96.7	224.8	362.3	24.6	70.3	85.4	44.8	2,860	3,623	2,012	44.1
SEm±	0.26	0.39	0.49	1.35	3.99	0.41	0.16	0.35	0.25	40.02	39.94	29.78	0.06
CD (P=0.05)	NS	1.22	NS	NS	NS	NS	0.50	NS	NS	NS	NS	NS	NS
Nutrient management													
75% RDF	41.8	57.0	89.4	207.4	322.6	19.2	69.2	82.3	43.3	2,535	3,226	1,754	44.0
100% RDF	42.4	62.0	94.3	226.6	363.1	25.0	70.0	84.9	44.8	2,861	3,631	2,004	44.1
125% RDF	43.4	63.8	97.6	230.3	372.2	26.3	70.2	85.8	44.7	2,937	3,722	2,062	44.1
75% RDF + R	42.2	58.8	93.6	214.6	338.4	20.3	69.5	83.7	43.7	2,661	3,383	1,850	44.0
100% RDF + R	42.7	62.8	97.1	231.2	379.2	26.2	70.8	85.8	45.1	3,011	3,792	2,131	44.3
125% RDF + R	44.1	64.9	101.4	234.2	384.7	27.0	70.3	86.3	45.6	3,059	3,847	2,152	44.3
SEm±	0.27	0.50	0.50	1.47	6.02	0.45	0.42	0.51	0.34	59.65	60.26	42.40	0.11
CD (P=0.05)	0.76	1.41	1.41	4.16	17.02	1.27	NS	1.44	0.96	168.69	170.42	119.91	NS

RDF, Recommended dose of fertilizer; R: *Rhizobium* (seed treatment); DAE, days after emergence; SMK, sound mature kernel; KW, kernel weight

parameters, there was no significant difference between the 100% RDF and 125% RDF treatments.

Soil-fertility status

Changes in soil N, P and K nutrient status under different groundnut variety and fertilizer level is reported in Table 2. Post-harvest soil fertility levels were found similar under both the varieties. Available N status of soil under variety 'TAG 24' increased from 126.7 kg/ha in 2017 to 135.9 kg/ha in 2019 and under variety 'TG 51' available N content increased from 128.8 kg/ha in 2017 to 135.1 kg/ha in 2019. Higher N content in soil was possibly owing to atmospheric nitrogen fixation in presence of *Rhizobium* in groundnut nodules (Sathiya *et al*., 2020). Higher N content of soil may favour higher biomass accumulation which increased the uptake of P and K form soil-available pool (Pasley *et al*., 2019; Haldar *et al*., 2019). As a result available P and K contents of the soil reduced over the year (Table 2).

Soil-N status varied significantly under different fertilizer treatments. Higher fertilizer dose and *Rhizobium* inoculation favoured the N accumulation in soil. The maximum available N was found in soil under 125% RDF with *Rhizobium* inoculation (136.8 kg/ha); however, it was statistically at par with 100% RDF with *Rhizobium* inoculation. Also, influence of *Rhizobium* inoculation on available P and K content was found insignificant. The experimental sites belongs to new alluvial zone of West Bengal and shows low to medium in fertility status, showing excellent response to fertilizer addition (Dasgupta *et al*., 2017; Ghosh, 2021; Haldar *et al*., 2019).

The net fertility status of the groundnut field showed a negative balance after completion of 3 years of experimentation for all the 3 nutrients (N, P and K) irrespective of variety and nutrient-management strategy (Table 3). Of the 2 varieties, 'TG 51' recorded higher net negative soil-fertility status over 'TAG 24' except P fertility. Among the different nutrient management, 75% RDF followed by 75% RDF + *Rhizobium* resulted higher net- nutrient depletion over the other treatments in the experiment. Variation in soil-fertility status and change in nutrient balance sheet in soil over years due to different nutrient management in field crop, confirming the findings of (Rana *et al.,* 2017).

Economics

Details of economic analysis under different fertilizer management practice is presented in Table 4. Both the varieties 'TAG 24' and 'TG 51' showed similar benefit: cost ratio. Moderate level of fertilizer (100% RDF) with *Rhizobium* inoculation resulted in the maximum benefit: cost ratio in variety 'TAG 24' (2.73), and variety 'TG 51' (2.71), being statistically at par. Though increasing level of

Table 2. Effect of variety and different nutrient levels on available nutrient in soil after groundnut harvesting

Treatment	Available N, P and K (kg/ha) in soil at harvesting											
	N				P				K			
	2016–17	2017–18	2018–19	Pooled	2016–17	2017–18	2018–19	Pooled	2016–17	2017–18	2018–19	Pooled
Varieties												
'TAG 24'	126.7	125.6	135.9	129.4	21.5	21.2	18.3	20.3	83.7	79.8	80.9	81.5
'TG 51'	128.8	124.3	135.1	129.3	21.6	21.7	19.0	20.8	82.0	78.1	77.5	79.2
SEm±	0.89	0.40	1.61	0.54	0.73	0.23	0.20	0.44	0.13	0.13	0.29	0.23
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.76	0.72
Nutrient management												
75% RDF	119.0	115.4	126.3	120.2	18.1	17.2	16.4	17.2	78.4	71.9	73.6	74.6
100% RDF	122.7	124.4	134.9	127.3	21.1	20.8	19.4	20.4	84.2	81.3	81.3	82.3
125% RDF	127.3	130.7	139.8	132.6	23.6	23.6	19.7	22.3	83.6	82.2	80.6	82.1
75% RDF + R	125.8	120.0	129.7	125.2	18.7	18.0	17.2	18.0	78.5	72.3	74.6	75.1
100% RDF + R	135.8	128.1	139.8	134.6	22.7	23.4	19.3	21.8	86.3	82.7	82.8	83.9
125% RDF + R	135.8	132.0	142.6	136.8	25.2	25.6	20.0	23.6	86.3	83.5	82.4	84.1
SEm±	1.12	0.73	1.13	0.80	1.02	0.68	0.62	0.50	0.54	0.54	0.59	0.51
CD (P=0.05)	3.29	2.15	3.33	2.26	2.99	2.00	1.83	1.41	NS	NS	1.74	1.44

RDF, Recommended dose of fertilizer; R, *Rhizobium* (seed treatment)

Table 3. Effect of groundnut variety and different nutrient levels on net soil-fertility status after completion of 3 years of experiment

Treatment	Net change in soil fertility status								
	N (kg/ha)			P (kg/ha)			K (kg/ha)		
	Initial	Final	Net gain/loss	Initial	Final	Net gain/loss	Initial	Final	Net gain/loss
Varieties									
'TAG 24'	152.8	135.9	-16.9	24.3	18.3	-6.0	129.2	80.9	-48.3
'TG 51'	152.8	135.1	-17.7	24.3	19.0	-5.3	129.2	77.5	-51.7
Nutrient Management (NM)									
75% RDF	152.8	126.3	-26.5	24.3	16.4	-7.9	129.2	73.6	-55.6
100% RDF	152.8	134.9	-17.9	24.3	19.4	-4.9	129.2	81.3	-47.9
125% RDF	152.8	139.8	-13.0	24.3	19.7	-4.6	129.2	80.6	-48.6
75% RDF + R	152.8	129.7	-23.1	24.3	17.2	-7.1	129.2	74.6	-54.6
100% RDF + R	152.8	139.8	-13.0	24.3	19.3	-5.0	129.2	82.8	-46.4
125% RDF + R	152.8	142.6	-10.2	24.3	20.0	-4.3	129.2	82.4	-46.8

RDF, Recommended dose of fertilizer; R, *Rhizobium*

Table 4. Effect of variety and different nutrient levels on the economics of groundnut

Treatment	Economics											
	Cost of cultivation (₹/ha)				Gross returns (₹/ha)				Benefit: cost ratio			
	2016–17	2017–18	2018–19	Pooled	2016–17	2017–18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled
'TAG 24' × 75% RDF	35,313	35,916	36,429	35,938	82,985	85,120	86,336	84,814	2.35	2.37	2.37	2.36
'TAG 24' × 100% RDF	36,521	36,998	37,553	36,967	97,510	99,155	95,008	97,224	2.67	2.68	2.53	2.63
'TAG 24' × 125% RDF	37,549	38,105	38,653	38,143	99,505	101,360	97,792	99,552	2.65	2.66	2.53	2.61
'TAG 24' × 75% RDF + R	35,787	36,380	36,927	36,357	89,110	87,675	88,256	88,347	2.49	2.41	2.39	2.43
'TAG 24' × 100% RDF + R	36,989	37,586	38,078	37,499	102,830	102,235	102,048	102,371	2.78	2.72	2.68	2.73
'TAG 24' × 125% RDF + R	38,110	38,696	39,158	38,604	102,515	103,705	104,160	103,460	2.69	2.68	2.66	2.68
'TG 51' × 75% RDF	35,330	35,979	36,488	35,881	86,205	87,430	87,936	87,190	2.44	2.43	2.41	2.43
'TG 51' × 100% RDF	36,434	37,002	37,579	37,000	98,735	92,505	99,584	96,941	2.71	2.50	2.65	2.62
'TG 51' × 125% RDF	37,596	38,119	38,629	38,063	101,885	94,535	102,752	99,724	2.71	2.48	2.66	2.62
'TG 51' × 75% RDF + R	35,912	36,471	36,996	36,454	93,730	89,355	93,600	92,228	2.61	2.45	2.53	2.53
'TG 51' × 100% RDF + R	37,023	37,494	38,124	37,592	104,405	95,235	105,984	101,875	2.82	2.54	2.78	2.71
'TG 51' × 125% RDF + R	38,067	38,625	39,237	38,646	104,685	97,720	109,472	103,959	2.75	2.53	2.79	2.69

RDF, Recommended dose of fertilizer; R, *Rhizobium* (seed treatment)

fertilizer over 100% RDF resulted higher gross return, benefit: cost ratio was lower in 100% RDF treatment. This was possibly due to higher cost involved in application of higher dose fertilizer. Fixation of atmospheric N and subsequent reduction in fertilizer N requirement under *Rhizobium* inoculation substantially improved the benefit: cost ratio as was evident in our experiment. Similar findings were reported by Kundu *et al*. (2023), where higher net returns were recorded with increasing application rate of fertilizer and biofertilizers. Higher crop growth and productivity with better uptake of nutrients resulted in higher return and benefit: cost ratio.

Better crop response was recorded when higher level of fertilizer was added to soil along with *Rhizobium* inoculation. However, the responses, including revenue generated and benefit: cost ratio were statistically at par even when fertilizer dose was increased after a certain level (100% RDF). It was concluded that, groundnut variety, 'TAG 24' along with 100% RDF + *Rhizobium* inoculation resulted better in terms of growth, yield and benefit: cost ratio, and may be recommended for this region for higher economic returns.

REFERENCES

Dasgupta, S., Sarkar, A., Chaitanya, A.K., Saha, A., Dey, A. and Mondal, R. 2017. Response of potato crop to integrated nutrient-management in the Indo-Gangetic alluvial soils of West Bengal, India. *Journal of Experimental Agriculture International* **16**(3): 1–10.

Donald, C.M. 1963. Competition among crop and pasture plants. *Advance in Agronomy* **15**: 1–118.

Gharge, P.V., Patil, P.R. and Karpe, A.H. 2017. Effect of rhizobium seed inoculation and secondary nutrient on the yield of groundnut (*Arachis hypogaea* L.) crop. *Trends in Biosciences* **10**(22): 4,448–4,451.

Ghosh, G. 2021. *Red and lateritic Soils and Agri-Productivity: Issues and Strategies*. The 11th Professor S.K. Mukherjee Memorial Lecture 2019. *Journal of the Indian Society of Soil Science* **67**(Supplement): 104–121.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*, edn 2, International Rice Research Institute, Manila, Philippines, John Wiley & Sons, New York, U.S.A.

Haldar, P., Sarkar, A., Roy, M. and Chowdhury, K. 2019. Sustaining paddy production through improved agronomic practices in the Gangetic alluvial zone of West Bengal. *Annals of Agrarian Science* **17**(2): 266–276.

Jackson, M.L. 1973. *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd, New Delhi, India.

Kundu, R., Sarkar, A., Moinuddin, G., Jash, S., Poddar, R. and Dey, A. 2023. Response of groundnut to phosphorus and bio-organics in Alfisols of Red and Laterite zone of India. *Journal of Plant Nutrition* **46**: 2,016–2,030.

Meena, R.S. and Yadav, R.S. 2015. Yield and profitability of groundnut (*Arachis hypogaea* L.) as influenced by sowing dates and nutrient levels with different varieties. *Legume Research* **38**(6): 791–797.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). United States, Department of Agriculture, Washington DC, USA.

Pasley, H.R., Cairns, J.E., Camberato, J.J. and Tony, J.V. 2019. Nitrogen fertilizer rate increases plant uptake and soil availability of essential nutrients in continuous maize production in Kenya and Zimbabwe. *Nutrient Cycling in Agroecosystems* **115**(8): 373–389.

Rana, L., Banerjee, H., Dutta, S.K., Ray, K., Majumdar, K. and Sarkar, S. 2017. Management practices of macronutrients for potato for smallholder farming system at alluvial soil (Entisols) of India. *Archives of Agronomy and Soil Science* **63**(14): 1,963–1,976.

Reddy, A.M., Reddy, A.P.K., Reddy, B.R., Naidu, M.V.S., Sudhakar, P. and Reddy, B.S. 2023. Effect of integrated rainwater-management practices on soil properties and productivity of groundnut (*Arachis hypogaea*) in arid and semi-arid regions of Andhra Pradesh. *Indian Journal of Agronomy* **68**(1): 54–59.

Sathiya, K., Hussainy, S.A.H. and Sridhar, P. 2020. Effect of agronomic management practices on the performance of rabi summer groundnut (*Arachis hypogaea*) under rice (*Oryza sativa*)–groundnut cropping system. *Crop Research* **55**(3 and 4): 107–112.

Sen, A., Batabyal, K., Mondal, S., Sarkar, A. and Sarkar, D. 2021. Use of Biofertilizers for sustainable agriculture. (In) *Agriculturally Important Microorganisms: Mechanisms and Applications for Sustainable Agriculture*. pp. 119–136, CRC Press, Boca Ratan, USA.

Singh, N., Joshi, E., Sasode, D.S., Dangi, R.S. and Chouhan, N. 2020. Soil fertility, macro and micro nutrient uptake and their use efficiencies under integrated nutrient management in groundnut (*Arachis hypogaea* L.). *International Journal of Chemical Studies* **8**(1): 1,983–1,987.

Singh, N., Joshi, E., Sasode, D.S., Rawat, G.S. and Tiwari, S. 2021. Response of rainy-season groundnut (*Arachis hypogaea*) to varying fertility levels and bioformulations. *Indian Journal of Agronomy* **66**(2): 241–245.

Subbiah, B. and Asija, G.L. 1956. Alkaline permanganate method of available nitrogen determination. *Current Science* **25**: 259.

Indian Journal of Agronomy **68** (4): 398–403 (December 2023)

Research Paper

Evaluation of food and fodder based cropping systems for sustaining productivity, resource use efficiency and profitability in western plain zone of Uttar Pradesh

L.R. MEENA[1], SAMRATH LAL MEENA[2], LALIT KUMAR[3], NATARAJA SUBASH PILLAI[4] AND T. RAM[5]

ICAR-Indian Institute of Farming Systems Research, Modipuram, Uttar Pradesh 250 110

Received: August 2022; Revised accepted: November 2023

ABSTRACT

A field experiment was conducted during 2015–16 to 2018–19 at the research farm of ICAR-Indian Institute of Farming Systems Research, Modipuram, Uttar Pradesh to assess the potential yield (PY), sustainability and resource use efficiency (RUE) of 7 cropping systems (CS), viz. maize + blackgram–pea–sorghum; cluster bean-wheat-teosinte; stylo-berseem-maize + cowpea; clitoria-mustard–greengram; rice–chickpea–okra; rice–wheat and sugarcane–wheat system. The experiment was laid out in randomized block design (RBD) with 3 replications. Among the different cropping systems, rice (*Oryza sativa* L.)–chickpea (*Cicer arietinum* L.)–okra (*Abelmoschus esculentus* L.) was found to be most superior in terms of wheat equivalent yield (WEY) (19.77 t/ha/year) and sustainable yield index (SYI=0.894). The highest land use efficiency (LUE) was recorded with cluster bean (C*yamopsis tetragonoloba* L.)–wheat (*Triticum aestivum* L.)–teosinte (*Zea* spp.) cropping system (95.16%) with 347 days of ground cover. Production efficiency was registered maximum with maize (*Zea mays* L.) + blackgram [*Vigna mungo* (L.) Hepper]–pea (*Pisum sativum* L.)–sorghum [*Sorghum bicolor* (L.) Moench] system (66.91 kg/ha/day), followed by rice–chickpea–okra system (62.25 kg/ha/day). Nevertheless, the highest net return (₹ 300.8×10^3/year) was realized with rice–chickpea–okra system. Total soil organic carbon (SOC) content was highest (1.34%) under stylo-berseem- maize + cowpea [*Vigna unguiculata* (L.) Walp.] cropping system in comparison to other cropping systems. Thus, it can be concluded that rice–chickpea–okra system proved more productive, remunerative (₹ 824/ha/day) and sustainable cropping system than the existing sugarcane (*Saccharum officinarum* L.)–wheat/rice–wheat cropping system in the western plain zone of Uttar Pradesh, India.

Key words: Crop diversification, Resource use efficiency, Sustainable yield index, Wheat equivalent yield

Crop diversification is a strategy to increase output on the same cultivable land while cultivating various crops from decreasing land resources. Often, it can mean adding extra crops to an existing rotation. Therefore, there is a huge demand for addition of fodder based alternate cropping systems on the bedrock of diversion in existing cropping systems like sugarcane (*Saccharum officinarum* L.)–wheat (T*riticum aestivum*) and rice (*Oryza sativa* L.)–wheat in western plain zone of Uttar Pradesh. Apart from this food and fodder based cropping systems when diversified with numerous crops at single time have a win-win situation by providing wider range of benefits to producers, consumers and environment (Honnali and Chittapur, 2014). Hence, farmers should emigrate over to favourite for raising more crops on the same piece of land owing to attains multiple demands of households as well as livestock. In addition to this, diversification of crops is aimed at reducing risk and vagaries due to climatic change and variability they are prevailing in the zone. Further, it was emphasized that high-remunerative crops and cropping systems should be included in the ecosystem services (ES), they shall be supplemented and eventually displaced synthetic external inputs and resulting in maintaining productivity for a longer period of time. Indeed, diversification in existing cropping systems would be more responsive to maintaining better soil health which leads to increased nutritional security for human beings and livestock. Thus, we will be able to identify suitable food and fodder based systems for the extensive group of marginal farmers (67%) in India (Bhargavi *et al.,* 2019). Therefore, with this aim the present study was planned to develop suitable alternate

[1]**Corresponding author's Email:** laxman.meena@icar.gov.in
[1,3]Principal Scientist, Division of Cropping Systems and Resource Management, ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, Uttar Pradesh 250 110; [2]Principal Scientist, [5]Senior Scientist, Division of Agronomy, [4]Principal Scientist and Head, Division of Agricultural Physics, ICAR-Indian Agricultural Research Institute, New Delhi 110 012

cropping systems in place of prevailing systems which could realize higher production, enhance resources used and be economically viable for the farmers of western plain zone of Uttar Pradesh.

MATERIALS AND METHODS

A field experiment was conducted during 2015–16 to 2018–19 at the research farm of ICAR-Indian Institute of Farming Systems Research, Modipuram, (29°04’38.8"N, 77°42’09.9"E, 237 m amsl), Uttar Pradesh which is classified as sub-tropical zone. During the experimentation (2015–16 to 2018–19) mean maximum temperatures varied from 30.4°C, 31.2°C, 30.7°C and 30.8°C and minimum temperatures 17.6°C, 17.3°C, 17.83°C and 18.1°C, respectively. The total annual rainfall at the experimentation periods (2015–16 to 2018–19) was received 710 mm, 665 mm, 736 mm and 790 mm, respectively, more than 80% of which was received through the south-west monsoon during July to September. Prior to the study, the soil was sampled from the entire experimental field at 0–30 cm depth and analyzed subsequently after making a composite sample. The initial study site was categorized as sandy loam soil having *p*H 7.99. The total soil organic carbon (SOC) was 0.89% (CHNS analyzer). Available N (176.6 kg/ha) was estimated by alkaline permanganate (KMnO4) method. Similarly, available soil P (29.3 kg/ha) was analyzed by (Jackson’s, 1973) method and available soil K (194.7 kg/ha) was estimated by NH_4OAc method. The 7 cropping systems, viz. maize (*Zea mays* L.) + blackgram [*Vigna mungo* (L.) Hepper]–pea (*Pisum sativum* L.) (vegetable)–sorghum [*Sorghum bicolor* (L.) Moench] (Fodder); cluster bean (*Cyamopsis tetragonoloba* L.)–wheat (*Triticum aestivum* L.)–teosinte (*Zea* spp.); stylo–berseem–maize + cowpea [*Vigna unguiculata* (L.) Walp.]; clitoria (Fodder)-mustard [*Brassica juncea* (L.) Czern.]-greengram [*Vigna radiata* (L.) R. Wilczek]; rice (*Oryza sativa* L.)-chickpea (*Cicer arietinum* L.)–okra (*Abelmoschus esculentus* L.); rice–wheat and sugarcane (*Saccharum officinarum* L.)–wheat were comprised. The net plot size of each treatment was 10 × 10 m^2. The experiment was laid out in randomized block design (RBD) and replicated thrice for 4 consecutive years (2015–16 to 2018–19) to identify most suitable cropping system through inclusion of pulses, cereals, oilseed, fodder, vegetable and cash crop (sugarcane) in the existing cropping systems. The details of varieties used, seed rate, spacing and fertilizer doses are given in Table 1. The sources of nutrients were urea, di-ammonium phosphate (DAP) and murate of potash (MOP)

Table 1. Production technologies for various crops in diversified cropping systems in western plain zone of Uttar Pradesh

Cropping system	Season	Cultivation practices			
		Crop/variety	Seed rate (kg/ha)	Spacing (cm)	Fertilizer (kg/ha) N-P_2O_5-K_2O
Maize + blackgram-pea-sorghum	*Kharif*	Maize/Dhaval Blackgram/Pant Urd-31	40-Maize 20-Blackgram	70 × 25-Maize 45 × 15-Blackgram	120:60:40-Maize 25:50:25-Blackgram
	Rabi	Pea/Arkel	75	30 × 10	50:70:70
	Summer	Sorghum/Kanpuri Safed	40	25 × 10	80:40:30
Cluster bean-wheat-teosinte	*Kharif*	Cluster bean/RGC1002	20	40 × 10	20:50:30
	Rabi	Wheat/DBW-16	80	22.5 × 5	120:60:60
	Summer	Teosinte/TLI	20	30 × 10	60:30:30
Stylo-berseem-maize + cowpea	*Kharif*	Stylo/Phule Kranti	10	30 × 10	30:60:20
	Rabi	Berseem/Mescavi	25	Broad Casted	20:80:60
	Summer	Maize/K125 Cowpea/EC4216	60 (25)	30 × 15 Maize 40 × 10 cowpea	120:80:40-Maize 20:60:40-Cowpea
Clitoria-mustard-greengram	*Kharif*	Clitoria/IGFRI-23-1	20	40 × 15	20:50:30
	Rabi	Mustard/RH749	5	30 × 15	80:40:40
	Summer	Greengram/SML668	20	45 × 30	25:50:25
Rice-chickpea-okra	*Kharif*	Rice/PB1121	25	20 × 10 (2–3 seedlings/hill)	120:60:60
	Rabi	Chickpea/Avrodhi	75	30 × 10	25:60:30
	Summer	Okra, Arkak, Anamica		60 × 30	75:50:60
Rice-wheat	*Kharif*	Rice/PB 1121	25	20 × 10 (2–3 seedlings/hill)	120:60:60
	Rabi	Wheat/DBW16	100	22.5 × 5	120:60:60
	Summer	-	-	-	-
Sugarcane-wheat	*Kharif*	Sugarcane/Co0238	7000 setts	90 × 30 (3 buds/set)	150:60:60
	Rabi	Wheat/ PBW226	100	22.5 × 5	120:60:60
	Summer	-	-	-	-

as per the recommended doses of respective crops. A uniform application of FYM (farmyard manure) @ 10 t/ha was applied during rainy (*kharif*) season only under all treatments because highly nutrients exhaustive triple crops were grown in quick succession round the year. The economic yield of component crops was converted into wheat equivalent yield (WEY), taking into account the prevailing farm gate price (₹/kg) of different crops. Production efficiency was deliberated as the ratio of kg (WEY/ha) to the total crop duration of the system in days. The productivity of different cropping systems was compared by calculating their economic wheat equivalent yield (WEY) as :

$$\text{WEY} = \frac{\text{Yield of each crop (kg/ha)} \times \text{Economic value of respective crop (₹/kg)}}{\text{Price of wheat grain (₹/kg)}}$$

The sustainable yield index (SYI) of the system was calculated based on the data from 4 years of system productivity as (Wanjari *et al*., 2004):

$$\text{Sustainable yield index} = \frac{\bar{Y} - \sigma}{\text{Y Max}}$$

where $\bar{Y}$, estimated mean yield; σ, estimated standard deviation; Y Max, observed maximum yield in the experiment over the years.

RESULTS AND DISCUSSION

Cropping systems extent

Among the different cropping systems, the short-duration crops, viz. pea (85 days), okra (90 days), and the cereal crops like sorghum, maize, rice, and wheat were mellowed approximately in 90, 105, 115 and 140 days, respectively. Similarly, fodder crops like cluster bean (115 days), stylo (102 days), clitoria (105 days), berseem (115 days), sorghum (90 days), teosinte (95 days), cowpea (105 days) were being matured at different period of times. The short-duration oilseed crop like mustard needed 115 days for maturity and pulse crops like greengram (85 days) and blackgram (115 days) took less time than other crops in various cropping systems. However, sugarcane crop required a longer growing period as compared to all other crops which were undertaken. But the cluster bean-wheat-teosinte cropping system had higher land use efficiency (95.16%) and followed by rice–chickpea–okra system (89.77%). The highest crops stand in the field was cluster bean–wheat–teosinte (347 days) and the next was sugarcane–wheat (329 days). Hence, selection of crops and their respective varieties plays pivotal role in the synergism among themselves toward efficient utilization of precious resources in order to increase overall productivity, profitability and environmental resilience (Verma *et al*., 2016).

System productivity

The pooled data for 4 years related to system productivity indicated significant (P≤0.05) variation among the different cropping systems. A highly productive and efficient cropping system was sugarcane–wheat (79.65 t/ha/year) compared to other cropping systems (CS). This is mainly because of higher production potential and remunerative price of sugarcane based cropping system as reported by Kumar *et al.,* (2021) and followed by maize+blackgram-pea-sorghum (68.97 t/ha/year), while the minimum system productivity was recorded in rice–chickpea–okra (13.04 t/ha/year) in terms of economic values (Table 2). Main and byproduct yields were varied under different cropping systems. But byproducts yield was higher in the case of fodder based system i.e. maize + blackgram–pea–sorghum as compared to other cropping systems in terms of dry matter (DM) production and followed by rice–wheat system (11.60 t/ha/year) and least with clitoria–mustard–greengram system (5.53 t/ha/year). Crop equivalent yield (CEY) is an important index for assessing performance of different crops under specified conditions. Cropping systems differed considerably (P ≤0.05) with respect to wheat equivalent yield. Wheat equivalent yield (WEY) at various cropping systems was increased significantly and maximum was estimated under rice–chickpea–okra system (19.77 t/ha/year). This might be owing to better production efficiency of these crops than other crops and the next best cropping system in terms of wheat equivalent yield was maize + blackgram–pea–sorghum (18.16 t/ha/year). This might be owing to synergistic effect of crops on each other in the newly developed cropping systems. At the same time, the minimum wheat equivalent yield was obtained in stylo–berseem–maize + cowpea system (14.11 t/ha/year). The fodder crops generally had lower market worth as compared to other crops undertaken in the study. The decreasing trend of WEY was noticed in prominent prevailing cropping systems (rice–wheat and sugarcane–wheat) because economic and ecological illnesses were observed higher in these systems. Therefore, other novel cropping systems have to be identified as suggested by Singh *et al.*, (2012). These results are in line with the outcomes of Singh and Kumar (2014).

Land use efficiency (LEU)

Intensification in sequential multiple cropping systems (MCS) by introduction of non-conventional/short-duration crop cultivars and intense input management is a common way to increase LUE, especially in irrigated agroecosystems. The LEU was observed to vary from 68.95 to 95.16% under different cropping systems. However, the highest LEU was attributed to the cluster bean- wheat-teosinte cropping system (95.16%) followed by rice–

Table 2. Effect of cropping systems on system efficiency, productivity and wheat equivalent yield (mean data of 4 years)

Cropping system	Crop season	Crop duration (days)	System efficiency: Land use efficiency (%)	System efficiency: Duration of the system (days)	System productivity: Economic yield (t/ha)	System productivity: By-product yield (t/ha)	Wheat equivalent yield (t/ha): 2015–16	2016–17	2017–18	2018–19	Mean
Maize + black gram (BG as intercrop) – pea–sorghum	*Kharif*	105-Maize 105- BG	76.16	278	6.87-Maize 0.62-BG	7.22-Maize 1.24-BG	16.73	17.38	18.38	20.17	18.16
	Rabi	85-Pea			3.67	3.84					
	Summer	90-Sorghum			57.81 (GF)						
Cluster bean–wheat–teosinte	*Kharif*	115-Cluster bean	96.16	347	2.94		15.92	16.36	15.04	15.43	15.68
	Rabi	140-Wheat			4.85	3.53					
	Summer	95-Teosinte			33.44	5.60					
Stylo–berseem–maize + cowpea (as Mixed crop)	*Kharif*	102-Stylo	87.85	319	15.23		13.94	14.45	14.14	13.92	14.11
	Rabi	115-Berseem			64.79						
	Summer	105-Maize 105-Cowpea			15.23 (GF)						
Clitoria–mustard–green gram	*Kharif*	105-Clitoria	86.96	322	44.45		14.73	14.84	14.65	16.55	15.19
	Rabi	115-Mustard			2.81	3.56					
	Summer	85-Green gram			1.35	1.97					
Rice–chickpea–okra	*Kharif*	115-Rice	89.77	328	5.54	6.01	17.84	18.40	20.40	22.45	19.77
	Rabi	125-Chickpea			1.96	2.53					
	Summer	90-Okra			5.54	2.41					
Rice–wheat	*Kharif*	115-Rice	68.95	252	5.65	6.05	13.94	14.03	14.08	14.60	14.16
	Rabi	140-Wheat			4.77	5.55					
	Summer	-			-	-					
Sugarcane–wheat	*Kharif*	310-Sugarcane	89.77	329	75.01	2.51	15.86	16.79	16.58	16.11	16.34
	Rabi	140-Wheat			4.64	5.36					
Statistical analysis	SEm±						0.57	0.61	0.77	1.01	1.13
	CD (P=0.05)					1.85	1.94	2.40	3.43	3.54	

BG, Blackgram; F, Fodder

chickpea–okra (89.77%) and sugarcane–wheat cropping system (89.77%) also, while the lowest was revealed in the case of rice-wheat system (68.95%). This was because of utilization of land for less duration in a year (252 days) and grown of 2 crops in a year and for the remaining period field was kept fallow (Table 2). These results were in conformity with the findings of Prasad *et al.,* (2013), who reported that intensification of rice based cropping sequence by greengram recorded markedly higher land use efficiency than normal cropping sequences that were undertaken and those without summer greengram. In multiple cropping, using short-duration crop cultivars with better management is a common way to increase LUE as also reported by Tetarwar *et al.*, (2023).

Sustainability

Rice–chickpea–orka cropping system (CS) articulated the highest sustainable yield index (SYI) of 0.894 (Table 3), this might be owing to higher production potential of these crops as well as greater perceptible market worth as compared to other ones which were undertaken in the enduring cropping systems during their respective growing seasons (*kharif*, *rabi* and summer). The next most superior cropping system (CS) in terms of SYI was maize+ balckgram–pea–sorghum (0.812), while the least SYI was noticed with the stylo–berseem–maize + cowpea (0.607) and very closed SYI was seen in case of rice–wheat system (0.610). This might be due to both these cropping systems have been produced lower biomass and their market prices being cheaper than other produced commodities. Similar results were also reported by Singh *et al*., (2011) and Kumar *et al.,* (2014) in food-fodder based cropping systems.

Nutrient dynamics

In general, fodder crops removed higher amounts of plant nutrients from the soil as compared to other crops grown in the different cropping systems because they produced higher tonnages of green biomass. The nutrient (NPK) uptake by the crops in various cropping systems was influenced significantly. Whereas, maximum N and P uptake (273.49 and 87.61 kg/ha) were estimated under clitoria–mustard–greengram sequence as compared to other systems (Table 3). However, the highest uptake of K by crops was realized in the rice–chickpea–okra system (433.03 kg/ha), while the negative trend was observed in sugarcane–wheat system (68.50, 46.28 and 174.25 kg/ha). A total sum of 299.25 and 182.94% higher turnover of N and P nutrients was observed under clitoria-mustard-greengram system as compared to sugarcane–wheat system. This could be possible due to mineralization of available soil nutrients being observed higher where enormous leguminous crops were integrated with other crops like wheat, maize, rice, sorghum etc.

Resource use efficiency

Resource use efficiency (RUE) derives an indication of ability of plant to convert utilization of resources to economic production under certain conditions. In the present study, monetary returns efficiency (MRE) was highest in case of rice–chickpea–okra system (₹824/ha/day) followed by maize + blackgram-pea-sorghum system (₹694/ha/day) and lowest monetary return efficiency was observed with the sugarcane–wheat system (₹540 ha/day). This could be owing to longer crop duration of sugarcane in the illustrated system, which fell in line with the findings of Jat *et al.,* (2011). The maximum and minimum production efficiency (PE) was found in maize + blackgram–pea–sorghum and stylo–berseem–maize + cowpea system (44.42 kg/ha/day), respectively. Lower production efficiency of fodder-based systems was due to lower economic value of fodder resulted into lower wheat equivalent yield (WEY t/ha) than other cropping systems (Kumar and Faruqui, 2009).

Economic analysis

The cost of cultivation of crops was highest in case of sugarcane–wheat system (₹132 × 10^3/ha) and followed by maize + blackgram–pea–sorghum (₹131.7 × 10^3/ha) (Table 3). Among the different systems, rice–chickpea–okra recorded the highest net return (₹300.8 × 10^3/ha). Whereas, inclusion of vegetables (okra and pea), pulses (chickpea, blackgram and greengram) and major cash crop (sugarcane) in the cropping systems, surged higher in productivity and fetched more market prices, thereby, increased in net monetary returns. The lowest net monetary return (₹197.1 × 10^3/ha) was accrued with sugarcane-wheat system because of high input demands compared with other cropping systems.

Soil fertility build-up

Soil chemical property like *pH* did not turned significantly over to potential status even after end of 4 years of experimentation conducted at the same site under different cropping systems (Table 4). The *pH* of the soil was near to neutral range of 7.55 and it was reduced under all cropping systems invariable from 7.49 to 7.74 and was within a practical range of crop production. The maximum availability of plant nutrients like N and P (211.02 and 42.82 kg/ha) was found with clitoria–mustard–greengram cropping system, but the available K (232.34 kg/ha) was higher under rice–chickpea–okra system. Whereas, legume crops

Table 3. Effect of cropping systems on yield sustainability, system efficiency and monetary advantage under Upper Gangetic Plain region of Uttar Pradesh (mean data of 4 years)

Cropping system	Sustainable yield index (SYI)	Nutrient uptake (kg/ha)			System efficiency		Returns in terms of monetary gain			
		N	P	K	Production efficiency (kg/ha/day)	Monetary efficiency (kg/ha/day)	Gross return (×10^3 ₹/ha)	Cost of cultivation (×10^3 ₹/ha)	Net return (×10^3 ₹/ha)	Return/ invested
Maize + blackgram (BG)–pea–sorghum	0.812	88.85	30.96	191.61	66.91	694	385.0	131.7	253.3	2.92
Cluster bean–wheat–teosinte	0.687	167.61	53.47	363.28	44.98	577	303.6	93.0	210.5	3.26
Stylo-berseem–maize + cowpea	0.607	213.67	79.34	324.03	44.42	563	284.1	78.7	205.4	3.61
Clitoria–mustard–greengram	0.662	273.49	87.61	411.79	47.67	602	299.5	79.7	219.9	3.76
Rice–chickpea–okra	0.894	203.46	70.89	433.03	62.25	824	411.9	111.1	300.8	3.71
Rice–wheat	0.610	140.83	49.31	308.58	56.23	575	284.7	74.7	209.9	3.81
Sugarcane–wheat	0.720	68.50	46.28	174.25	50.12	540	329.8	132.7	197.1	2.48
SEm±		3.23	2.24	17.95	-	-	5.97	-	-	-
CD (P=0.05)		10.07	7.00	55.93	-	-	18.59	-	-	-

Table 4. Effect of diversified cropping systems on physico-chemical properties of the soil

Cropping system	*p*H	Organic C (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Maize + blackgram–pea–sorghum	7.74	1.007	187.04	31.90	209.33
Cluster bean–wheat–teosinte	7.73	1.064	201.51	30.91	223.73
Stylo-berseem–maize + cowpea	7.59	1.337	204.58	34.02	228.50
Clitoria–mustard–greengram	7.55	1.159	211.02	42.82	215.04
Rice–chickpea–okra	7.72	1.325	193.28	39.18	232.34
Rice–wheat	7.56	1.129	197.46	33.18	222.95
Sugarcane–wheat	7.49	0.929	179.37	30.30	191.00
SEm±	0.05	0.088	5.63	2.79	8.53
CD (P=0.05)	0.16	0.262	19.55	8.36	28.64
Initial	7.99	0.891	176.57	29.26	194.67

such as stylo–berseem–maize + cowpea had maximum positive response in tune of build-up total organic carbon (1.337%) and increased in the extend of 50.15% higher over to initial total soil organic carbon status (0.891%). The least total organic carbon (OC) strata in soil was found under the sugarcane–wheat system (0.929%) because both the crops were highly nutrients exhaustive in nature and they added meager quantity of trash and straw in the soil after their harvesting and decaying of organic matter was also power into the soil.

This study concludes that the inclusion of vegetables and pulses (rice–chickpea–okra and maize + blackgram–pea–sorghum) in the cropping systems significantly improved the system productivity and profitability along with improvement in soil health and resource use efficiency as compared to prevailing high input requiring cereal-based (rice–wheat and sugarcane–wheat) systems in western plain zone of Uttar Pradesh.

REFERENCES

Bhargavi, B., Behera, U.K., Rana, K.S. and Singh, Raj. 2019. Productivity, resource-use efficiency and profitability of high value crops embedded in diversified cropping systems. *Indian Journal of Agricultural Sciences* **89**(5): 821–827.

Honnali, S.N. and Chittapur, B.M. 2014. Efficient cropping systems and their energetic for sustainable irrigated tropical ecosystems. *Indian Journal of Agronomy* **59**(4): 556–560.

Jat, H.S., Meena, L.R., Mann, J.S., Chand, Roop, Chander, Subash and Sharma, S.C. 2011. Relative efficiency of different cropping sequences in a farmers participatory research program in semi-arid agroecosystem of Rajasthan. *Indian Journal of Agronomy* **56**(4): 321-–327.

Jackson, M.L.1973. *Soil Chemical Analysis*, pp. 498. Prentice Hall of India Pvt. Ltd., New Delhi.

Kumar, Sunil and Faruqui, S.A. 2009. Production potential, resource use efficiency and economic viability of diversified cropping systems in the western plain zone of Uttar Pradesh. *Indian Journal of A*gronomy **54**(1): 36–41.

Kumar, M., Mitra, S., Mazumdar, S.P., Majumdar, B., Saha, A.R., Singh, S.R., Pramanick, B., Gaber, A., Alsanie, W.F. and Hossain, A. 2021. Improvement of soil health and system productivity through crop diversification and residue incorporation under Jute-based different cropping systems. *Agronomy* 11: 1,622.

Kumar, Santosh, Bohra, J.S., Rana, Kiran, Goswami, Gargi and Mishra, P.K. 2014. Yield, nutrient content and nutrient uptake of rice as influenced by rice-based cropping system in Varanasi of eastern Uttar Pradesh, India. *Ecology Environment and Conservation Journal* **20**(2): 787–792.

Prasad, D., Yadav, M.S. and Singh, C.S. 2013. Diversification of rice (*Oryza sativa*)-based cropping systems for higher productivity, profitability, and resource-use-efficiency under the irrigated ecosystem of Jharkhand. *Indian Journal of Agronomy* **58**(2): 77–83.

Singh, D. K. and Kumar, P. 2014. Influence of diversification of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system on productivity, energy and profitability under farm conditions. *Indian Journal of Agronomy* **59**(2): 200–203.

Singh, R.K., Bohra, J.S., Nath, T., Singh, Y. and Singh, K. 2011. Integrated assessment of diversification of rice–wheat cropping system in Indo-Gangetic plain. *Archives of Agronomy and Soil Science* **57**(5): 489–506.

Singh, R.D., Shivani, Khan, A.R. and Chandra, N. 2012. Sustainable productivity and profitability of diversified rice-based cropping systems in an irrigated ecosystem. *Archives of Agronomy and Soil Science* **58**(8): 859–869.

Tetarwar, J.P., Ram Baldev, Bijarnia, Anju and Singh, Pratap. 2023. Performance of diversified cropping sequences for productivity, profitability and land use efficiency under South-eastern Rajasthan, *India. Indian Journal of Agronomy* **68**(1): 77–82.

Verma, Rakesh Kumar, Shivay, Yashbir, Kumar, Dinesh and Ghasal, Prakash Chand. 2016. Productivity and profitability of wheat (*Triticum aestivum*) as influenced by different cropping systems and nutrient sources. *Indian Journal of Agronomy* **61**(4): 429–435.

Wanjari, R.H., Singh, M.V. and Ghose, P.K. 2004. Sustainable yield index: An approach to evaluate the sustainability of long term intensive cropping system in India. *Journal of Sustainable Agriculture* **24**(4): 39–56.

Indian Journal of Agronomy **68** (4): 404—412 (December 2023)

Research Paper

Effect of crop residue and weed management on weed incidence, soil moisture and yield of chickpea

M.P. SAHU[1], ML KEWAT[2], A.K. JHA[3], V.K. CHOUDHARY[4], BADAL VERMA[5], JITENDRA PATIDAR[6], VIKASH SINGH[7] AND PRATIK SANODIYA[8]

ICAR-Directorate of Weed Research, Maharajpur, Jabalpur 482004, Madhya Pradesh, India

Received: December 2022; Revised accepted: November 2023

ABSTRACT

Chickpea is a major pulse crop which is grown and consumed by the Indian people. Due to poor weed competition ability of chickpea and very few weed management options, yield of chickpea is drastically reduced under vertisols. Therefore, the present study related to weed management and crop residues on weed incidence, yield attributing character and yield of chickpea was conducted at Research Farm of JNKVV, Jabalpur (MP), India. A field experiment was undertaken in split plot design with 3 replications and 4 weed-management treatment in main-plot and four crop residues as sub-plot. The main plot treatments were pendimethalin 38.7% CS at 1 kg/ha as pre plant incorporation (PPI), hand weeding at 30 days after sowing (DAS), hand hoeing at 30 DAS and weedy check. Four crop residues mulch (CRM) were, wheat straw (WSM), paddy straw (PSM) and soybean haulm (SHM) each at 5 t/ha and control where no mulch material was applied. Results revealed that imposition of hand weeding at 30 DAS recorded with least weeds with lesser weed biomass resulting in higher weed control efficiency (WCE). However, weedy check recorded maximum weed count and dry weight. Pendimethalin 1 kg/ha recorded lower weed prevalence and weed dry weight. It was similar to hand hoeing done at 30 DAS. Among applied CRM, PSM recorded lower weed density and dry weight with higher WCE and soil moisture at 30 DAS and was superior over control plots. Hand weeding at 30 DAS recorded with higher yield attributing traits *viz,* pods/plant, seed/pod and seed index resulted higher seed yield (1,604 and 1,731 kg/ha respectively in 2018–19 and 2019–20). It was at par with pendimethalin at 1 kg/ha. The lower yield attributes and yield was recorded in weedy check plots. Among CRM, spreading of PSM give more pods and seeds/pod with higher seed index resulted in higher seed yield (1515 and 1593 kg/ha in 2018–19 and 2019–20 respectively) over others. Thus, application of PSM at 5 t/ha with one hand weeding at 30 DAS or with pendimethalin can be suggested for significant weed control and higher seed yield in chickpea.

Key Words: Hand weeding, Mulch, Pendimethalin, Soil moisture, Yield

India is the largest Chickpea (*Cicer arietinum* L.) grower and consumer in the world with area, production and productivity of 9.44 Mha and 10.13 MT and 10.73 ka/ha respectively. Among the states Madhya Pradesh is first in area, production and productivity of 3.34 Mha, 4.41 MT and 1344 kg/ha respectively (Directorate of Economics and Statistics, 2019). The availability of food grains increased from 144.1 kg/year in 1951 to 179.6 kg/year during 2019. Increasing in the nation's population per capita availability of pulses has been reduced from 25 kg/year to 17.5 kg/year in 2019 (Anonymous, 2020). Legume crops are the main source of protein in the diet of Indian people. Rhizobium take the food material from chickpea and provide atmospheric nitrogen to plant in available from causes behind this it take lesser nitrogen from the soil (Havlin *et al.,* 2014). Weeds are drastically yield reducer in chickpea under irrigated condition, it reduces yield of chickpea by more than 70% when no weed control measures were adopted (Sahu *et al.,* 2022). During, rabi season, broadleaf weeds are major yield reducer as compared with grassy weeds (Baghel, 2018). The weeds in irrigated situations tend to offer severe competition for growth resources and cause drastic yield reduction to the extent of 75 per cent (Balyan and Bhan, 1984; Singh and Singh, 1992). Chickpea suffers a lot from broad leaved weeds as compared to grassy weeds (Baghel, 2018). Among the broad

[1]**Corresponding author's Email:** munipratapag@gmail.com, amitagcrewa@rediffmail.com

[1]Senior Research Fellow, [4]Senior Scientist, [7]Ph.D. Scholar, ICAR-Directorate of Weed Research, Maharajpur, Jabalpur, Madhya Pradesh 482 004; [2]Professor, [3]Assistant Professor, [5]Ph.D. Scholar, [6]Senior Scientist, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482 004; [8]Assistant Professor (Agronomy), Banaras Hindu University, Bananas, Uttar Pradesh 221 005

leaved weeds, *Chenopodium album, Melilotus alba, Melilotus indica, Vicia sativa, Lathyrus aphaca,* and *Anagallis arvensis* etc. mostly affect the chickpea crop at Jabalpur (Sahu *et al*., 2022 and Chauhan *et al.,* 2017). In chickpea weed control measures done by mechanical, cultural and chemical methods. Mechanical methods *viz.*, hand weeding and hand hoeing are mostly adopted for control of weeds but these are time and labour consuming methods. On the other hand, herbicides provide effective weed control and found more economical but cause negative impacts on environment and human health. Mulches are an effective non-chemical material for weed suppression, which is a cultural method for weed management (Mahmood *et al.,* 2015). Crop residues are available in huge quantity in the field as crops are harvested by combines and forcing the farmer to go burning. It is therefore, necessary to make judicious use of left out crop residues in the field in the form of mulch. When mulch is placed on or spread over the soil surface, it protect the soil from erosion, conserve soil moisture and suppress weed growth. Beside this, helps in proper growth and development of crop plants by modifying soil temperature, providing better nutrient and soil moisture availability (Sarangi *et al*., 2021). In addition to this, the crop mulches release allelopathic chemicals like hydroxamic and phenolic acids, and effectively reduce herbicide use in order to maintain an eco-friendly environment and a cost-effective weed control (Lam *et al.,* 2012). Hence, there is need to adjudge the suitable combination of herbicides with straw mulches to curb the dry matter production of weeds and find out eco-friendly weed control measure in chickpea (Nosrati *et al.,* 2017). Since knowledge about efficacy of pendimethalin 38.7% CS as pre-plant incorporation (PPI) alone and in combination with crop mulch is very few, therefore present experiment was conducted to judge the suitable weed control practices and straw mulches on weed growth, yield attributing traits and yield of chickpea.

MATERIALS AND METHODS

A two year field experiment was carried out during *Rabi* 2018-19 and 2019-20 at Live Stock Farm, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur situated at 23.18^0 N latitude 79.99^0 E longitude and an altitude 412 Metre above the mean sea level. Soil of experimental area was sandy loam in texture, neutral in reaction (pH 7.24) having medium organic carbon (0.61 %) and available N (365.20 kg/ha), medium in phosphorus (17.97 kg/ha) and high in available K (308.12 kg/ha). The 16 treatments comprising of four weed control practices viz. Pendimethalin 38.7% CS 1 kg *a.i.* /ha as PPI, Hand Weeding at 30 DAS, Hand Hoeing at 30 DAS and Control (No weed control) as a main plot treatments and four crop mulch *viz.,* Wheat straw 5 t/ha, Paddy straw 5 t/ha, Soybean straw 5 t/ha and Control (No mulch) were assigned in sub plot treatments and were laid out in a split plot design with three replications. Chickpea variety 'JG 14' which is early maturing and heat tolerant variety, developed by JNKVV, Jabalpur in 2009 and potential yield 18-19 q/ha was sown in row 30 cm apart, using 80 kg/ha seeds. Fertilization is done in chickpea @ 20 kg N, 60 kg P_2O_5 and 20 kg K_2O/ha as basal dose by urea, single super phosphate (SSP) and muriate of potash, respectively. Application of pendimethalin as PPI was applied before 2 DAS with hand knapsack sprayer fitted with flat-fan nozzle at spray volume of 500 l/ha and crop straw mulches were spread after seed emergence. Weed prevalence and weed biomass were recorded at 30 DAS with the help of 1 x 1 m quadrate by dropping randomly at two places in each plot. Weeds were removed and species wise weed dry weight was recorded after drying in hot air oven (60 ± 1^0C for 24 hours). Weed control efficiency was also calculated at 30 DAS. Soil Moisture was calculated by aluminum box method on the basis of fresh and oven dry weight of soil. Growth parameters *viz.,* plant height; branches per plant, nodule per plant, crop biomass were recorded at different time intervals. Yield attributing traits *viz.,* pods per plant, seeds per pod and seed index (100 seed weight) were recorded at maturity. Finally, seed and haulm yields were recorded treatment wise. Weed control efficiency, harvest index, weed index and economic viability of treatments, soil moisture and temperature above and below the mulch and soil microbial count were determined from the data generated. Tabulation and statistical analysis of data have been done for testing the significance of variation among the different treatments with the OPSTAT software which are summarized here under.

RESULTS AND DISCUSSION

Associated weed flora

Chickpea field was infested by dicot weed. In the experimental area, chickpea field infested with *Cichorium intybus* (26%), *Medicago truncatula* (28%) and *Melilotus indica* (18%). However, other weeds like, *Anagalis arvensis* (14%) and *Chenopodium album* (14%) was also present in less numbers Figure 1 show the per cent of dominant weeds in the experiential area. Sahu *et al.* (2020), Jha *et al*., 2014, Tanisha *et al*., 2022 and Patel *et al*., 2023 also reported similar weeds in Jabalpur region.

Weed density and dry weight

Weed density and weed dry weight in 2018–19 and 2019–20 at 30 DAS presented in table 1 and 2. Hand weeding done at 30 DAS recorded lower population and weed biomass of *Cichorium intybus, Medicago*

Table 1. Effect on weed control practices and straw mulches on density of weeds at 30 DAS during *rabi* 2018–19 and 2019–20

Treatment	Weed density (no./m^2)									
	Cichorium intybus		*Medicago truncatula*		*Melilotus indica*		*Anagalis arvensis*		*Chenopodium album*	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Weed control practices										
Pendimethalin	4.41	4.86	4.09	4.52	2.91	3.33	3.30	3.59	3.02	3.34
1kg *a.i.*/ha as PPI	(19.83)	(23.83)	(16.83)	(20.50)	(8.17)	(10.83)	(10.50)	(12.50)	(8.83)	(10.83)
Hand weeding at 30 DAS	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Hand hoeing at 30 DAS	3.46	4.00	2.87	3.45	2.57	3.04	3.07	3.39	2.49	2.87
	(11.67)	(15.67)	(7.83)	(11.50)	(6.33)	(9.00)	(9.17)	(11.17)	(5.83)	(7.83)
Weedy check	5.59	5.95	5.69	6.00	4.27	4.58	4.33	4.56	4.13	4.37
	(32.67)	(36.67)	(32.17)	(35.67)	(19.50)	(22.17)	(18.33)	(20.33)	(16.67)	(18.67)
SEm±	0.33	0.30	0.18	0.18	0.28	0.27	0.11	0.09	0.05	0.05
CD (P=0.05)	1.15	1.07	0.65	0.63	1.00	0.94	0.37	0.33	0.18	0.16
Straw Mulches 5 t/ha										
Wheat straw	3.40	3.74	3.21	3.55	2.53	2.83	2.77	2.98	2.38	2.63
	(14.33)	(17.33)	(12.17)	(15.00)	(8.00)	(10.00)	(8.67)	(10.17)	(6.00)	(7.50)
Paddy straw	2.94	3.34	2.74	3.13	2.06	2.42	2.42	2.66	2.10	2.38
	(10.50)	(13.50)	(9.33)	(12.00)	(4.67)	(6.67)	(6.50)	(8.00)	(4.83)	(6.33)
Soybean Straw	3.63	3.96	3.53	3.83	2.79	3.07	3.00	3.20	2.81	3.03
	(16.83)	(19.83)	(15.50)	(18.00)	(9.17)	(11.17)	(10.50)	(12.00)	(9.33)	(10.83)
No Mulch	4.20	4.48	3.88	4.17	3.08	3.34	3.22	3.40	3.04	3.24
	(22.50)	(25.50)	(19.83)	(22.67)	(12.17)	(14.17)	(12.33)	(13.83)	(11.17)	(12.67)
SEm±	0.13	0.12	0.05	0.05	0.07	0.07	0.03	0.03	0.05	0.05
CD (P=0.05)	0.39	0.35	0.16	0.15	0.20	0.20	0.10	0.09	0.15	0.14

Figures in parenthesis are original values and have been transformed ($\sqrt{X+0.5}$) before statistical analysis, NS= Non Significant

Table 2. Effect on weed control practices and straw mulches on dry weight of weeds at 30 DAS during *rabi* 2018–19 and 2019–20

Treatment	Weed dry weight (g/m^2)									
	Cichorium intybus		*Medicago truncatula*		*Melilotus indica*		*Anagalis arvensis*		*Chenopodium album*	
	2018–19	2019–20	2018–19	2019–20	2018–19	2019–20	2018–19	2019–20	2018–19	2019–20
Weed control practices										
Pendimethalin	1.11	1.18	0.93	0.97	0.82	0.86	0.79	0.80	0.81	0.84
1kg *a.i.* ha^{-1} as PPI	(0.77)	(0.92)	(0.38)	(0.46)	(0.18)	(0.25)	(0.12)	(0.14)	(0.16)	(0.20)
Hand weeding at 30 DAS	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Hand hoeing at 30 DAS	0.97	1.05	0.81	0.85	0.79	0.83	0.77	0.78	0.78	0.80
	(0.46)	(0.61)	(0.15)	(0.23)	(0.13)	(0.20)	(0.09)	(0.11)	(0.11)	(0.15)
Weedy check	1.55	1.62	1.19	1.23	1.02	1.05	0.88	0.89	0.96	0.98
	(2.07)	(2.30)	(0.95)	(1.04)	(0.58)	(0.66)	(0.26)	(0.29)	(0.41)	(0.46)
SEm±	0.07	0.07	0.04	0.04	0.03	0.04	0.01	0.01	0.01	0.01
CD (P=0.05)	0.24	0.23	0.13	0.14	0.11	0.12	0.02	0.02	0.02	0.02
Straw Mulches 5 t/ha										
Wheat straw	1.01	1.06	0.87	0.90	0.81	0.84	0.78	0.79	0.79	0.80
	(0.58)	(0.70)	(0.25)	(0.32)	(0.17)	(0.22)	(0.10)	(0.12)	(0.11)	(0.14)
Paddy straw	0.91	0.96	0.81	0.84	0.76	0.79	0.75	0.76	0.77	0.78
	(0.36)	(0.46)	(0.18)	(0.22)	(0.09)	(0.13)	(0.07)	(0.08)	(0.09)	(0.11)
Soybean Straw	1.14	1.20	0.92	0.95	0.84	0.87	0.80	0.81	0.84	0.86
	(0.98)	(1.13)	(0.38)	(0.43)	(0.22)	(0.28)	(0.14)	(0.16)	(0.21)	(0.25)
No Mulch	1.28	1.33	1.03	1.07	0.93	0.96	0.82	0.83	0.87	0.89
	(1.37)	(1.54)	(0.67)	(0.75)	(0.41)	(0.47)	(0.18)	(0.20)	(0.27)	(0.31)
SEm±	0.024	0.023	0.013	0.014	0.014	0.014	0.002	0.002	0.004	0.004
CD (P=0.05)	0.39	0.35	0.16	0.15	0.20	0.20	0.10	0.007	0.15	0.14

Figures in parenthesis are original values and have been transformed ($\sqrt{X+0.5}$) before statistical analysis, NS= Non Significant

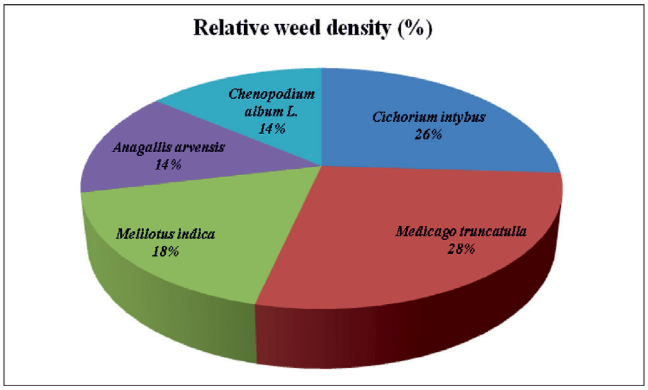

Figure 1. Relative weed density at 30 DAS (Mean data of 2 year)

truncatula Melilotus indica, Anagalis arvensis and Chenopodium album because all weeds were eliminated manually from the field during critical period to provide favourable environment for crop growth. Application of pendimethalin 38.7% CS 1 kg a.i. /ha as PPI recorded lower weed density and dry weight of , *Cichorium intybus* (19.83 and 23.83/m^2 and 0.77 and 0.92 g/m^2),*Medicago truncatula* (16.83 and 20.50/m^2 and 0.38 and 0.46 g/m^2) *Melilotus indica* (8.17 and 10.83 no. /m^2 and 0.18 and 0.25 g/m^2), *Anagalis arvensis* (10.50 and 12.50/m^2 and 0.12 and 0.14 g/m^2) and *Chenopodium album* (8.83 and 10.83/m^2 and 0.16 and 0.20 g/m^2) over weed check due to check the weed growth through checking cell division resultant lower weed density and dry weight was recorded. hand hoeing done at 30 DAS also recorded lower weed density and dry weight due to same observational day operation. It cut down inter row weeds but not cut intra row weeds. Sneha (2020), Sahu *et al* 2020a, Yadav *et al.* 2023, Jha and Kewat 2013 and Tiwari *et al.* 2011a also presented similar results. Maximum weed density and dry weight of different weed species were recorded in control plots due to uninterrupted growth of all weed during critical period of crop growth.

Paddy straw at the rate of 5 t/ha recorded lower density and dry weight of *Cichorium intybus* (14.33 and 17.33/m^2 and 0.58 and 0.70 g/m^2), *Medicago truncatula* (12.17 and 15.00 no. /m^2 and 0.25 and 0.32 g/m^2), *Melilotus indica* (8.0 and 10.0 no. /m^2 and 0.17 and 0.22 g/m^2), *Anagalis arvensis* (8.67 and 10.17/m^2 and 0.10 and 0.12 g/m^2) and *Chenopodium album* (6.50 and 7.50/m^2 and 0.11 and 0.14 g/m^2) over all the mulches in 2018-19 and 2019-20 respectively. Paddy straw provide uniform covering of row space between crop plants and reduce light and air availability to the various weed species. Wheat straw also provide good control of all weed species in relation to weed density and dry weight over no mulch but statistically similar to soy bean straw mulch at the rate of 5 t/ha. Among the straw mulch, no mulch plots recorded higher density and dry weight of all weed species due to uninterrupted growth of all weed species during critical growth period (Sahu *et al.,* 2022 and Jagat *et al*., 2009).

Weed control efficiency

Weed control efficiency was significantly affected by weed control treatments in chickpea. Maximum weed control efficiency of *Cichorium intybus, Medicago truncatula, Melilotus indica, Anagalis arvensis and Chenopodium album* (100% WCE) were recorded in hand weeding at 30 DAS. It was due to elimination of weed, lower weed density and dry weight were recorded and caused receiving maximum weed control efficiency over all the treatments. Hand hoeing at 30 DAS (1 kg *a.i./*ha as PPI) also provide higher weed control efficiency of *Cichorium intybus* (77.97 and 73.61%), *Medicago truncatula* (84.08 and 78.31%), *Melilotus indica* (77.33 and 69.12%), *Anagalis arvensis* (69.12 and 61.22%) and *Chenopodium album* (73.08 and 68.03 %) followed by pendimethalin 1kg/ ha due to presence of lower weed biomass. The weed control efficiency was minimum under weedy check plots where weed control was not done it was due more weeds during the critical period (Jha *et al.* 2014, Notsari *et al*. 2017 and Tiwari *et al.* 2011a).

No mulch recorded lower weed control efficiency of various weed species due to absence of any mulch material between row space weed severities was more in respective plots.Weed control efficiency was slightly increase in soybean straw mulch (5 t/ha). It was due to suppression of all weeds increased weed control efficiency of weeds slightly. Wheat straw mulch (5 t/ha) increased weed control efficiency of *Cichorium intybus, Medicago truncatula, Melilotus indica, Anagalis arvensis* and *Chenopodium album*by (72.01 and 69.73, 73.32 and 69.79, 70.72 and 66.50, 66.50 and 60.53 and 72.51 and 69.31%, respectively). Among straw mulches, paddy straw (5 t/ha) recorded maximum weed control efficiency (82.34 and 79.82, 81.13 and 78.47, 85.20 and 79.71, 79.71 and 72.52 and 79.07 and 75.96% in 2018-19 and 2019-20, respectively) and proved superior to other straw mulches due to proper covering of space between two row and reduce availability of light and air weed incidence was reduced (Singh and Guru, 2011).

Soil Moisture pattern

Soil moisture content not affected significantly by weed control treatments, but among straw mulches, paddy straw mulch at the rate of 5 t/ha received significantly higher soil moisture (15.75 and 22.63% respectively) at 30 DAS in chickpea. It was due to proper covering of openspace reduces the direct exposure of sun light and air reduces water loss from evapo-transpiration in the soil profile resultant more soil moisture was store in the soil. Wheat and

Table 3. Effect of weed control practices and straw mulches on yield attributing characters and yield of chickpea at 2018–19 and 2019–20

Treatment	Yield attributing characters						Yield				Economics	
	Pods/plant		Seeds/pod		Seed index (%)		Seed yield (kg/ha)		Haulm yield (kg/ha)		B:C ratio	
	2018–19	2019–20	2018–19	2019–20	2018–19	2019–20	2018–19	2019–20	2018–19	2019–20	2018–19	2019–20
Weed control practices												
Pendimethalin 1 kg *a.i.*/ha as PPI	41.48	45.55	1.64	1.74	15.12	15.20	1,421	1,561	3,351	3,191	1.78	2.02
Hand weeding at 30 DAS	44.83	48.92	1.70	1.80	14.98	15.06	1,604	1,731	3,719	3,559	1.80	1.98
Hand hoeing at 30 DAS	33.25	35.95	1.62	1.72	14.78	14.86	1,208	1,322	2,989	2,829	1.54	1.76
Weedy check	20.17	21.23	1.60	1.70	14.85	14.93	869	868	2,673	2,513	1.17	1.24
SEm±	1.24	1.49	0.06	0.06	0.85	0.85	89.29	86.42	127.32	127.32		
CD (P=0.05)	4.39	5.25	NS	NS	NS	NS	314.99	304.86	449.138	449.13		
Straw Mulches 5 t/ha												
Wheat straw	37.57	39.90	1.68	1.78	14.99	15.07	1,339	1,469	3,325	3,165	1.44	1.62
Paddy straw	40.38	44.58	1.70	1.80	15.20	15.28	1,515	1,593	3,497	3,337	1.80	1.98
Soybean Straw	32.13	35.58	1.59	1.69	14.79	14.87	1,187	1,279	2,968	2,808	1.43	1.61
No Mulch	29.65	31.58	1.59	1.69	14.75	14.83	1,062	1,143	2,941	2,781	1.61	1.79
SEm±	1.00	0.97	0.04	0.04	0.22	0.22	36.76	56.45	106.72	106.72		
CD (P=0.05)	2.95	2.84	NS	NS	NS	NS	107.94	165.73	313.36	313.357		

wheat straw mulch at the rate of 5 t/ha also increase soil moisture due to minimization in sun light penetration in to the soil. Among the mulch treatment, no mulch plot recorded lower soil moisture during both the years (10.49 and 12.55 %, respectively) at 30 DAS (Sahu *et al.,* 2020a).

Yield attributes

Yield attributing traits, only pods per plant were affected significantly due to weed control treatments. However, seeds per pod and seed index were remained unaffected under different weed control treatments since this character are governed by genetic factors. Among all the treatments, minimum numbers of pods per plant were recorded under weedy check plots (20.70). Thin and lanky crop plants under severe weed stress, could not assimilate and partitioned enough photosynthates for formation of pods in crop plants hence led to minimum number of pods per plant in weedy check plots. But pods per plant increased marginally in the plots receiving hand hoeing at 30 DAS due to better growth and partitioning of photosynthates under poor weed dry weight and density than check plots. The pods per plant were significantly higher in plots receiving application of pendimethalin (1 kg *a.i.*/ha as PPI). Better growth and development under these treatments resulted in more flowers and better fertilization, which in turn favoured more pod formation as confirmed by Sneha (2019). However, hand weeding done at 30 DAS had the highest number of pods/plant due to timely removal of weeds coupled with pulverization of soil, which encouraged better growth and development of flowers including their fertilization and finally recorded maximum pods per plant (Chaudhary *et al.*, 2005 and Chandrakar *et al.*, 2015) . Similarly pods/plant were significantly influenced due to application of various straw mulches. However, seeds/pod and seed index were remained unchanged under various straw mulch applications. This character is regulated by genetic factors. The pods per plantwere minimum under check plots where no mulch was applied due to severe crop-weed competition during critical period and poor growth of crop plants. Soybean straw mulch (5 t/ha) increased pods per plant marginally (9.57%) due to utilization of growth resources and healthy and taller plants in comparison to check plots. However, wheat straw mulch (5 t/ha) caused further increase in the pods per plant due to better growth and development under these treatments, resulting in more flower initiation and fertilization in the plants. However, paddy straw when applied in chickpea (5 t/ha) recorded maximum pods per plant (42.48). Optimum utilization of water, light, space and nutrient by the plants led to produce more flowers and better partitioning of photosynthates from source to sink and finally more number of pods per plant than other mulches Jagat *et al.,* (2009).

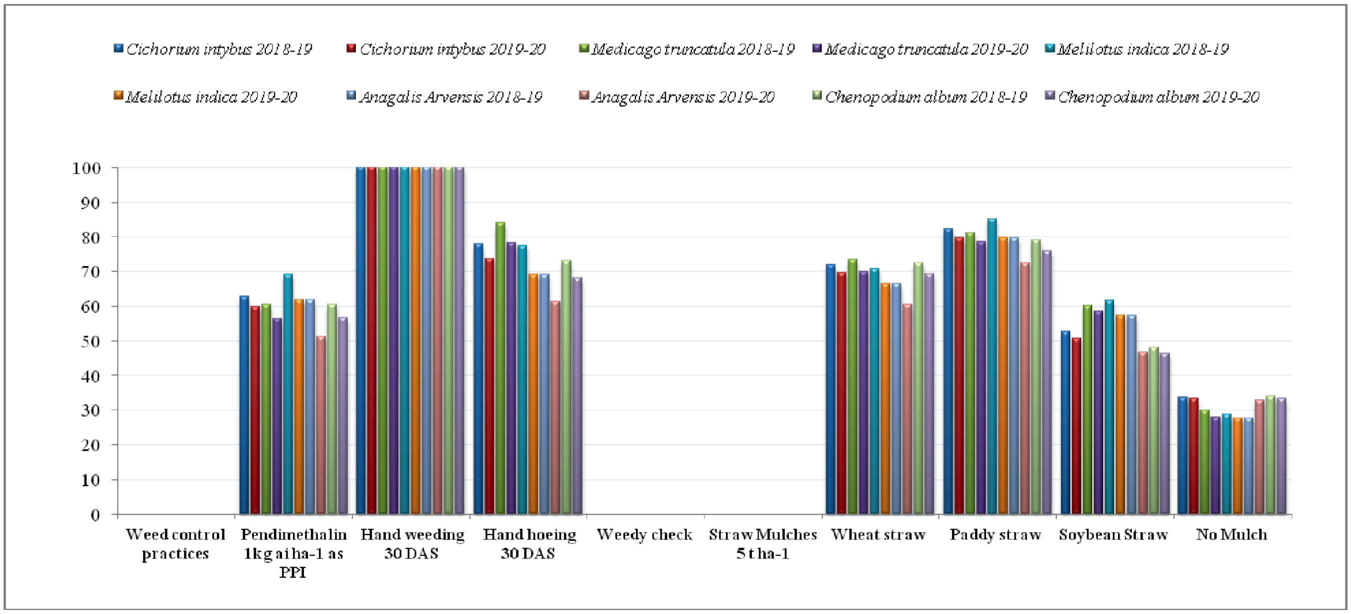

Fig. 1. Effect of weed control practices and straw mulches on weed control efficiency at 30 DAS 2018–19 and 2019–20

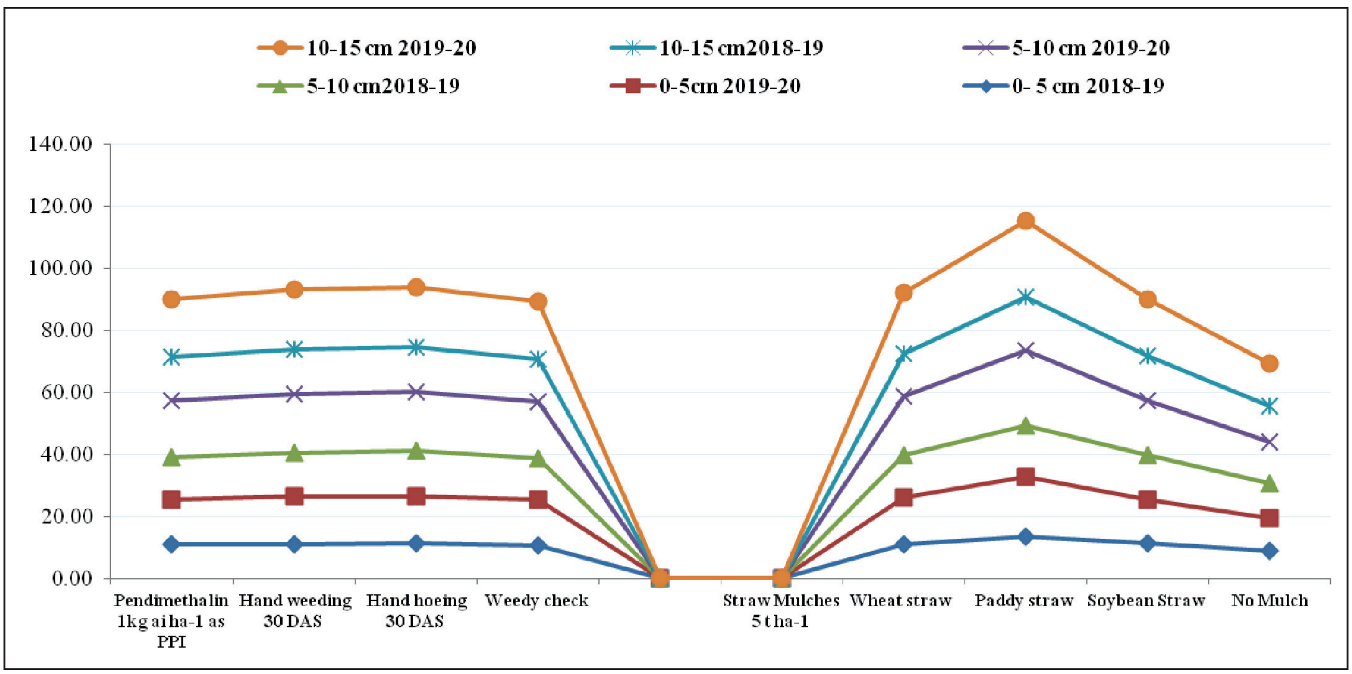

Fig. 2. Effect of weed control practices and straw mulches on soil moisture content (0-5,5-10 and 10-15cm depth) at 30 DAS 2018–19 and 2019–20

Yields

Weed control treatments affect seed and haulm yield significantly. Among weed control treatment lower seed yield (869 and 868 kg/ha) and haulm yield (2673 and 2513 kg/ha) was recorded in weedy check plots. It was due to more crop weed competition during critical period resultant less photosynthetic material was accumulated. it was increased appreciably in plots receiving mechanical and chemical weed control. Pendimethalin at the rate of 1 kg *a.i*/ha as PPI increase seed yield (1,421 and ,1561 kg/ha) and haulm yield (3351 and 3190 kg/ha) of chickpea due to proper control of weeds during critical growth period resulting more source and sink was available to the plants. It was at par with hand hoeing at 30 DAS. Among weed control treatment, maximum seed yield (1,604 and 1,731 kg/ha) was recorded in hand weeding done at 30 DAS and proved significantly superior over other weed control treatments due to elimination of all sort of weeds during critical period but it was at par to pendimethalin 1 kg a.i./ha. Sahu *et al*., (2020) also reported similar result. Application of straw mulches affects seed and haulm yield of chickpea significantly. Among straw mulches minimum seed (1062 and 1143 kg/ha), haulm (2941 and 2781 kg/ha) due to severe crop weed competition during critical period resultant lower seed and haulm yield were recorded. However, soybean straw mulch (5 t/ha) increased seed and haulm yield slightly. But wheat straw mulch (5 t/ha) increase seed yield appreciably. But application of paddy straw (5 t/ha) recorded maximum seed yield (1515and 1593 kg/ha) and proved significantly superior to other straw mulches due to proper suppression of weeds during critical period resulting higher seed yield (Sahu *et al*., 2020 and Choudhary *et al.,* 2012). Among weed control treatment lower B:C ratio was recorded in control plots. Hand weeding received higher B:C ratio (1.80) in 2018-19, but pendimethalin 1 kg/ha received higher B:C ratio (2.02) in 2019-20.Among straw mulches paddy straw received higher b:c ratio (1.80 and 1.98) in 2018-19 and 2019-20 respectively. However, no mulch plots had lower B:C ratio due to higher weed growth resulting in less economic yield and hence lower B:C ratio was recorded.

CONCLUSION

From this study it may be concluded that minimum density of grassy and total weeds and dry-matter accumulation by them at all stages was observed in hand weeding done at 30 DAS, being statistically at par with application of pendimethalin 38.7% CS application 1 kg/ha as PPI. The higher seed yield, haulm yield and B: C ratio gave in with application of pendimethalin1 kg/ha and similar to hand weeding. Application of paddy and wheat straw mulch 5 t/ha significantly lowered weed density and dry weight, increased weed control efficiency resulting recorded higher yield attributes, yield and B:C ratio of chickpea.

REFERENCES

Anonymous, 2020. Pocket book of Agricultural Statistics 2019. Directorate of Economics and Statistics, Department of Agriculture Co-operation and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare, Govt. of India, New Delhi

Baghel, R. 2018. Bio-efficacy of pendimethalin (38.7%CS) as PPI against complex weed flora in Chickpea. Thesis M.Sc., JNKVV Jabalpur, Madhya Pradesh.

Balyan, R.S. and Bhan, V.M. 1984. Promising herbicides for weed control in chickpea. *Indian Journal of Weed Science* **16**(2): 69–75.

Chandrakar, S., Sharma, A. and Thakur, D.K. 2015. Effect of weed management on weeds and yield of chickpea varieties. *Advance Research Journal of Crop Improvement* **6**: 1–4.

Chaudhary, B.M., Patel, J.J. and Delvadia, D.R. 2005. Effect of weed management practices and seed rates on weeds and yield of chickpea. *Indian Journal of Weed Science* **37**(3/4): 271–272.

Choudhary, V.K., Kumar, P.S. and Bhagawati, R. 2012. Integrated weed management in blackgram under mid hills of Arunachal Pradesh. *Indian Journal of Agronomy* **57**(4): 382–385.

Chauhan Abhishek, Jha Girish, Chourasiya Ajay, Jha Amit and Joshi Jitendra 2016. Effect of tillage and weed management practices and growth productivity and energy analysis of late sown chickpea. International Journal of Agriculture Sciences **9**(5): 3,779–3,781.

Directorate of Economics and Statistics. 2019. Department of Agriculture and Cooperation. 2019-2020, (http://www.agricoop.nic.in).

Havlin, J.L., Tisdale, S.L., Neslon, W.L., Beaton, J.D. 2014. *Soil Fertility and Fertilizers-An Introduction to Nutrient Management* 8th Edition. pp. 512.

Jagat, D.R., Robin, B., Julie, L. and John, M. Doxhbury. 2009. Impact of mulching on wheat yield and weed floras in the Mid-Hills of Nepal. *Nepal Agriculture Research Journal* **9**: 21–27.

Jha, A.K., Shrivastva, A., Raghuvansi, N.S., Kantwa, S.R. 2014. Effect of weed control practices on fodder and seed productivity of Berseem in Kymore plateau and Satpura hill zone of Madhya Pradesh. *Range Management and Agroforestry* **35**(1): 61–65.

Jha Amit and Kewat M.L. 2013. Weed compositions and seed bank as affected by different tillage and crop establishment techniquesin rice-wheat system. *Indian Journal of Weed Science* **45**(1): 19–24.

Lam, Y., Sze, C.W., Tong, Y., Ng, T.V., Tang, S.C.W., Man, Ho J.C., Xiang Q., Lin, 5X and Zhang, Y. 2012. Research on the allelopathic potential of wheat. *Journal of Agricultural Science* **3**(8): 979–985.

Mahmood, A., Ihsan, M.Z., Khaliq, A., Hussain, S., Cheema, Z.A., Naeem, M., Daur, I., Hussain, H.A., Alghabari, F. 2015. Crop residues mulch as organic weed management strategy in maize. *Clean Soil, Air, Water* **44**(3): 317–324.

Nosrati, I., Nassab, A.D.M., Shakiba, M.R. and Amini, R. 2017. Evaluating the cultural and physical methods and reduced doses of herbicide in integrated weed management of chickpea. *Journal of Agricultural science and sustainable production* **27**(7): 87–102.

OPSTAT software available online at CCS, Haryana Agriculture University. Available: www.hau.ernet.in

Patel, R., Jha, A.K., Verma, B., Porwal, M., Toppo, O. and Raghuwanshi, S. 2023. Performance of pinoxaden herbicide against complex weed flora in wheat (*Triticum aestivum* L.). *International Journal of Environment and Climate Change* **13**(7): 339–345.

Sahu, M.P., Kewat, M.L., Jha, A.K., Sharma, J.K. and Sondhia S. 2020. Identification of Problematic Weeds in Chickpea Crop in Jabalpur District of Madhya Pradesh. *International Journal of Current Microbiology and Applied Sciences* **9**(9): 973–977.

Sahu, M.P., Kewat, M.L., Jha, A.K., Sharma, J.K. and Sondhia S.2020a. Weed dynamics as affected by practices and straw mulches in chickpea. *International Journal of Chemical Studies* 2020; **8**(4): 1857-1859.

Sahu, M.P. , Kewat, M.L., Jha, A.K., Sondhia, S., Choudhary, V.K., Jain, N., Patidar, J., Kumar,V., and Verma, B. 2022. Weed prevalence, root nodulation and chickpea productivity influenced by weed management and crop residue mulch. *Agricultural Mechanization in Asia, Africa and Latin America* **53**(6) ISSN: 00845841.

Sarangi, S.K., Maji, B., Sharma, P.C., Digar, S., Mahanta, K.K., Burman, D., Mandal, U.K., Mandal, S. and Mainuddin, M. 2021. Potato (*Solanum tuberosum* L.) cultivation by zero tillage and paddy straw mulching in the saline soils of the Ganges Delta. *Potato Research* **64**(2): 277–305. https://link.springer.com/article/10.1007%2Fs11540-020-09478-6.

Singh, G. and Singh, D. 1992. Weed crop competition studies in chickpea. *Indian Journal of Weed Science* **24**(1 and 2): 1–5.

Singh, P. and Guru, S.K. 2011. Effect of rice straw incorporation on weed management and crop growth in rice, *Indian Journal of Weed Science* **43**(3 and 4): 236–238.

Sneha, G.2019. Bio-efficacy of pendimethalin as PPI against complex weed flora in Chickpea. Thesis M.Sc., JNKVV Jabalpur, Madhya Pradesh.

Tanisha, Nirala, Jha, A.K., Verma, B., Yadav, P.S., Anjna, M., Bhalse, L. 2022. Bio efficacy of pinoxaden on weed flora and yield of wheat (*Triticum aestivum* L.). *Biological Forum – An International Journal* **14**(4): 558–561.

Tiwari, R.K., Dwived, B.S., Deshmukh, G., Pandey, A.K. and Jha Amit. 2011. Effect of weed control treatments on growth of little seed cannary grass and productivity of wheat. *Indian Journal of Weed Science* **43**(3 and 4): 239–240.

Tiwari, R.K., Khan I.M., Singh, Nirmla and Jha, A. 2011a. Chemical weed control in wheat through on form demonstration in Rewa district of Madhya Pradesh. *Indian Journal of Weed Science* **43**(3 and 4): 215–216.

Yadav, P.S., Kewat, M.L., Jha, A.K., Sahu, M.P., Verma, B. and Toppo, Oscar. 2023. Floristic composition of weeds as influence by sowing time and herbicides in berseem. *Ecology, Environment and Conservation Journal* **29**(3): 64–68.

Indian Journal of Agronomy **68** (4): 413–419 (December 2023)

Research Paper

Relationship between weather factors and planting dates with references to growth and yield of potato (*Solanum tuberosum*) varieties

YOGESH KUMAR[1], RAJ SINGH[2] AND ANIL KUMAR[3]

Chaudhary Charan Singh Haryana Agricultural University, Hisar, 125 004

Received: September 2021; Revised accepted: October 2023

ABSTRACT

A field experiment was conducted during the winter season of 2016–17 and 2017–18 at the research farm of the Department of Agricultural Meteorology, College of Agriculture, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana to quantify the effect of different planting dates on the growth and yield of potato (*Solanum tuberosum* L.) cultivars. The experiment comprised 12 treatment combinations involving 4 date of sowing, viz. D_1, 8 October; D_2, 22 October; D_3, 5 November and D_4, 15 November as main plot treatment and viz. 3 varieties V_1, 'Kufri Bahar', V_2, 'Kufri Pushkar' and V_3, 'Kufri Surya', as sub-plot treatment in a split-plot design, replicated 4 times. The maximum tuber yield was recorded in D_2 (21.9 tonnes/ha) as compared to the other sowing dates and the lowest in D_4 (16.5 tonnes/ha). Among the varieties, 'Kufri Pushkar' had a significantly higher tuber yield (23.2 tonnes/ha) than 'Kufri Bahar' (18.0 tonnes/ha) and 'Kufri Surya' (16.6 tonnes/ha) during the crop season. Plant height, dry matter accumulation and biological yield were positively correlated with wind speed, rainfall and rainy days. The number of leaves/plant and leaf-area index (LAI) was significantly, negatively correlated with maximum and minimum temperatures, whereas it showed significant positive correlations with wind speed. Evening relative humidity was also positively correlated with LAI and tuber yield of potatoes. However, improved cultivars along with ideal planting windows at micro-level identification were the best way to mitigate the challenges posed by the climate in potatoes in near future.

***Key words*:** Crop-weather relationship, Growth parameters, LAI, Planting dates, Potato, Yield attributes

The potato (*Solanum tuberosum* L.) is the 3rd most important food crop in the world after rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) and is consumed by more than a billion people worldwide (Jansky *et al*., 2019). India is presently ranked second in global potato production. It is cultivated over an area of approximately 2.25 million ha, with a production of 54.23 million ton and productivity of 26.60 t/ha (DES, 2021). In Haryana, potato is cultivated over an area of approximately 31000 ha with a production of 0.80 million tonnes and productivity of 26.25 tonnes/ha (DES, 2021). India faces a tremendous challenge to increase the productions of all food crops, including potatoes to meet future needs.

Potato is regarded as a high-potential food-security crop because of its ability to provide a potential yield of high-quality product per unit input with a shorter life-cycle of crops (mostly <120 days) than major cereal crops like maize (*Zea mays* L.). The potato provides nutritious food in a diversity of environments. Meteorological elements governing the growth, development, production and quality of potato tubers at a given site are air and soil temperatures, solar radiation, photoperiod, soil moisture and evapotranspiration. Potato is best adapted to cool climates such as tropical highlands with mean daily temperatures between 15ºC and 18ºC. Higher temperatures favour foliar development and retard tuberization. In addition, heat stress leads to a higher number of smaller tubers/plant; lower tuber specific gravity with reduced dry-matter content, and usually to paler skin color of the tubers (Adane *et al*., 2010).

Vegetables production is considered to be particularly important in satisfying world food demand. Specific research therefore, is needed to evaluate the effects of environmental factors that crop encounters during their growth on production. Very early planting may expose the crop to higher temperature at the reproductive stage while late planting may result in low biomass production and affect tuber development due to higher temperature conditions at

[1]**Corresponding author's Email:** yogeshgujjar62@gmail.com
[1]Assistant Professor (Agricultural Meteorology), CCS Haryana Agricultural University, College of Agriculture, Bawal (123501) Rewari, Haryana, [2]Principal Scientist, [3]Assistant Scientist (Agricultural Meteorology), Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana 125 004

maturity of winter (*rabi*) crops including potatoes. The crop management practices, such as changing planting date or selection of varieties modifying plant duration will affect potential yield. Potato varieties have divergence for morphological, physiological and yield potential that allow them to respond differently to planting environment is another factor that may affect the growth and yield of potatoes. The objectives of the paper are to understand the extent that the optimum planting window along with improved varieties in the Subtropical region has adapted to changing climatic conditions. Therefore, this study was planned to investigate the effect of planting dates and varieties interaction on growth and yield of potato under different planting dates, and effects on crop weather relationships in sub-tropical environment.

MATERIALS AND METHODS

An experiment was conducted in the winter (*rabi*) season of 2016–17 and 2017–18 at the research farm (29° 10' N, 75° 46' E, 215.2 m above mean sea level) of the Department of Agricultural Meteorology, Chaudhary Charan Singh Haryana Agricultural University, Hisar. The climate of Hisar is mainly characterized by its continental location on the outer margins of the monsoon region. It is situated in the tract of semi-arid and subtropical monsoonal climate. In winter only 2–3 rainy showers are received due to western disturbances followed by low temperature. The occurrence of frost on certain days is also not an unusual feature for the place. The coefficient of variation for annual rainfall ranges between 45% and 50%, whereas the seasonal variation during monsoon season can go up to 80% and during the winter season around 65%. The average annual rainfall in the tract is around 450 mm, most of which is received during south–west monsoon season.

The weekly values of weather parameters prevailed during the *rabi* (2016–17 and 2017–18) were worked out based on daily data recorded at Agromet Observatory, CCS HAU, Hisar situated just beside the experimental site along with normal values for various weather parameters. Weekly mean maximum and minimum temperature values (Tmax and Tmin) during both crop season were deviated from normal in the entire crop season. A comparison between 2 seasons showed that, mean maximum and minimum temperature prevailed from emergence to physiological maturity was higher during 2016–17 than subsequent crop season. The fluctuations of mean weekly morning and evening relative humidity (RHm and RHe) were higher throughout the crop season 2016–17 as compared to 2017–18 except the span of vegetative stage where these were lower than the normal. It varied much uneven and abruptly oscillating in reproductive stage during 2016–17 from normal.

The amount of rainfall (RF) and its distribution were uneven and erratic rainfall during the crop growing season in 2016–17 and it was uniform in 2017–18. The *rabi* season of 2016–17 received a total of 53.2 mm rainfall with 3 rainy days out of which vegetative phase had received no rainfall but at reproductive stage, it received much higher rainfall. Only 2 rainy days were recorded during whole crop season 2017–18 and received a total of 14.7 mm. During 2016–17, crop seasons received above normal rainfall (53.2 mm, whereas normal rainfall is 36.4 mm) and in 2017–18, crop season recorded below normal (14.7 mm). The weekly mean sunshine hour values (BSS) were fluctuated much throughout the crop season as compared to normal during both season, during 2017–18 was characterized by lower sunshine duration. The mean weekly wind speed values (WS) during both crop seasons were abnormally fluctuated from normal. They are in the range of 1.1 to 5.0 km/h and 0.7 to 5.1 km/h during 2016–17 and 2017–18. The seasonal mean weekly cumulative pan evaporation value (PE) was 38.7 mm in 2016–17 and 41.8 mm during 2017-18 as against the normal of 36.4 mm and thus leading to non-stress conditions for most of the growing season and more-moist conditions were available in 2017–18.

The soil was low in organic carbon and nitrogen, medium in phosphorus and rich in potassium and slightly alkaline in reaction. The physico-chemical properties of the experimental soil were analysed through various methods of estimation and found that the percentage of sand (56.7 and 55.2), silt (25.8 and 26.6) and clay (17.8 and 18.4) during 2016–17 and 2017–18. The textural class of soil was sandy loam and the chemical composition of the soil was estimated through various standard methods of estimation like soil *p*H (1:2 soil water suspensions) with the use of glass electrode *p*H meter was 8.1 and 8.0 during 2016–17 and 2017–18.

The electrical conductivity (dS/m at 25 ºC) was estimated by conductivity bridge method was 0.68 and 0.71 and organic carbon (%) by Walkley and Blacks wet oxidation method was 0.43 and 0.49 during 2016–17 and 2017–18. The available N (kg/ha by alkaline permanganate method was 162, available P_2O_5 (kg/ha) by Olsen's method was 25 and 26 and available K_2O (Kg/ha) by flame photometer method was 321 and 320 during 2016–17 and 2017–18, respectively.

The main plot of 16 treatment combinations of 4 planting dates, viz. D_1, 8 October; D_2, 22 October; D_3, 5 November and D_4, 15 November on 3 varieties (V_1, 'Kufri Bahar', V_2, 'Kufri Pushkar' and V_3, 'Kufri Surya', as a subplots treatment, were arranged in a split plot design with 4 replications. Each plot was 5.0 m wide and 3.6 m long. Presprouted potato was sown manually from seed potatoes–small tubers at 60 cm × 20 cm apart at a depth of 5 cm to 10 cm. The recommended dose of nitrogen (150 kg N/

ha), phosphorus (50 kg P_2O_5/ha) and potassium (100 kg/ha) were applied. The full dose of diammonium phosphate, muriate of potash and half dose of nitrogen were applied before sowing and the remaining N was top dressed after 25–30 days after sowing at earthing up. For growth and yield attribute 5 plants in each plot were tagged randomly in the field. Plant height was measured from the base of the plant to the tip of the main stem. The green leaf-area (cm^2) was recorded using leaf-area meter. The sampled plants were separated into roots, stems, leaves and reproductive parts (stolon and tuber) and sun-dried. Further, the samples were oven-dried at 65ºC to 70ºC to a constant weight. The biomass/dry-matter accumulation in different plant parts was converted to gram per plant.

Yield parameters, viz. tubers/plant and tuber weight/plant, were recorded at the time of digging. The tuber yield was recorded from net plot. The growth and yield parameters, viz. numbers of tubers/plant, tuber weight (g/tuber), tuber yield/plant (g), tuber yield (tonnes/ha), biological yield (tonnes/ha) and harvest index (%) were subjected to statistical analysis using OPSTAT software available at www.hau.ernet.in. The recorded data were averaged and statistically analysed as per Sheoran *et al*. (1998) using the statistical programme OPSTAT.

RESULTS AND DISCUSSION

Growth parameters

All the growth parameters increased with the advancement of crop stages from emergence to physiological maturity. Among the planting dates, the maximum plant height was recorded in D_2 followed by D_1, D_3 and the minimum in D_4 during both the crop seasons. The plant height was recorded higher in D_2 (15.5 cm) and lower in D_4 (9.33 cm) at emergence, respectively. At physiological maturity, D_2 attained the maximum height, i.e. 44.8 cm and 36.4 cm respectively. However, height of crop plant was more in reproductive phases during 2017–18 as compared to 2016–17. Among varieties, the 'Kufri Pushkar' recorded maximum plant height (13.2 cm to 43.9 cm) followed by 'Kufri Bahar' (11.7 cm to 39.3 cm), 'Kufri Surya' (10.3 cm to 38.8 cm) from emergence to physiological maturity in the pooled year, respectively. Modisane (2007) also concluded that, plant height was higher in October sown potato crop than the late sown one. Thongam *et al.* (2017) also reported that number of leaves/plant were more in 10 October sown crop as compared to other dates in potato for assessing growth and development of potato, supports the our results of these findings.

The leaves/plant were significantly more in D_2 (176) than in D_4 (134) at tuber bulking stages during crop season, stage after this it started declining up to physiological maturity (Table 1). Among the varieties, 'Kufri Pushkar'

Table 1. Effect of planting dates on plant height (cm) and number of leaves/plant of potato varieties at various phenophases (pooled data of 2 years)

Treatment	Plant height (cm)					Number of leaves/plant				
	Emergence	Stolonization	Tuber initiation	Tuber bulking	Physiological maturity	Emergence	Stolonization	Tuber initiation	Tuber bulking	Physiological maturity
Date of planting										
D_1, 8 October	11.4	20.5	31.7	36.1	42.3	15.4	50.9	111	162	129
D_2, 22 October	15.5	22.1	37.6	41.3	44.8	17.9	60.3	125	176	136
D_3, 4 November	10.5	17.8	30.1	35.5	39.1	12.8	40.2	106	154	123
D_4, 15 November	9.3	15.3	24.4	33.5	36.4	10.1	34.5	99.5	134	113
SEm±	0.31	0.72	0.80	1.08	0.57	0.36	1.46	2.12	8.17	3.20
CD (P=0.05)	1.00	2.35	2.58	3.51	1.88	1.17	4.74	6.86	NS	10.1
Varieties										
V_1, 'Kufri Bahar'	11.6	21.2	31.1	37.5	39.3	14.2	47.8	118.7	146	131
V_2, 'Kufri Pushkar'	13.2	20.2	34.9	42.3	43.9	17.9	55.9	118.9	169	136
V_3, 'Kufri Surya'	10.3	15.3	28.4	30.7	38.8	9.98	35.6	94.1	128	108
SEm±	0.26	0.65	0.46	0.75	1.01	0.39	1.56	1.45	6.62	3.88
CD (P=0.05)	0.76	1.91	1.34	2.20	NS	1.15	4.58	4.27	19.4	11.4

*NS, Treatment difference not significant

produced maximum number of leaves/plant (18 to 135) followed by 'Kufri Bahar' (14.2 to 130) and 'Kufri Surya' (9.98 to 108.2) from emergence to physiological maturity. The maximum numbers of stems/hill were recorded in D_2 (16.1) followed by D_1 (13.6), D_3 (12.4) and the minimum in D_4 (10.8) at physiological maturity. Among the varieties, 'Kufri Pushkar' recorded maximum number of stem/hills (1.94 to14.9) followed by 'Kufri Bahar' (1.46 to 13.4) and 'Kufri Surya' (1.13 to 11.4) from emergence to physiological maturity during the seasons. Thongam *et al.* (2017) also reported that number of stem/hill were more in 10 October sown crop as compared to other dates in potato for assessing growth and development of potato.

Leaf-area index (LAI) of potato crop increased with the advancement of crop stage from emergence to tuber bulking stage and decreased thereafter at physiological maturity and it followed similar pattern of number of leaves/plant (Table 2). Among the planting dates, LAI was significantly highest in D_2 followed by D_1, D_3 and the lowest in D_4 from emergence to physiological maturity. The D_2 gained the highest LAI, i.e. 4.32, at tuber bulking stage. However, LAI was more in all the phenophases during 2017–18 as compared to 2016–17. 'Kufri Pushkar' accumulated more LAI followed by 'Kufri Bahar' and 'Kufri Surya' in both the crop seasons. 'Kufri Pushkar' accumulated maximum LAI, i.e. 4.24, at tuber bulking stage; this might be owing to more photosynthetically active radiation absorption and elongated vegetative phase was recorded by 'Kufri Pushkar' than other varieties and lower in 'Kufri Bahar'.

Dry-matter accumulation (ultimate production capability of the crop) was more in D_2 followed by D_1, D_3 and D_4 planting. All planting dates differed significantly in producing dry- matter at all the important phenophases. Dry matter accumulation increased linearly from the emergence to physiological maturity because dry matter accumulation depends on the amount of solar radiation intercepted by the crop (Haverkort *et al*., 2004). Thongam *et al*. (2017) also reported that dry matter was more in October 10 sown crop followed by other dates and it was the least in December in Maharashtra region. However, late sown crop suffered from lower bright sunshine hours, and consumed lower growing degree-days and photothermal units at physiological maturity also. Our findings supporting the results of Haverkort *et al*. (2004).

Yield and its attributes A significant effect of treatment was noted on the tuber yield as well as yield constituents of potato varieties (Table 3). Among the planting dates, the crop sown on (D_2, 22 October) showed successive increments in yield attributes, viz. tubers/plant, tuber weight (g/tuber), tuber yield/plant (g), tuber yield (tonnes/ha), biological yield (tonnes/ha) and harvest index (%). The

Table 2. Effect of planting dates on number of stem/hill and leaf area index of potato varieties at various phenophases (pooled data of 2 years)

Treatment	Number of stems/hill					Leaf-area index				
	Emergence	Stolonization	Tuber initiation	Tuber bulking	Physiological maturity	Emergence	Stolonization	Tuber initiation	Tuber bulking	Physiological maturity
Date of planting										
D_1, 8 October	1.54	9.99	11.8	12.8	13.6	0.58	1.32	3.10	3.60	1.74
D_2, 22 October	2.53	11.4	14.8	15.8	16.1	0.73	1.90	3.95	4.32	2.33
D_3, 4 November	1.24	9.25	10.8	11.7	12.4	0.49	1.48	2.83	3.31	1.47
D_4, 15 November	0.72	8.28	9.60	10.2	10.8	0.23	0.89	1.76	2.86	1.19
SEm±	0.16	0.37	0.68	0.52	0.32	0.05	0.14	0.15	0.12	0.11
CD (P=0.05)	0.53	1.22	2.22	1.69	1.05	0.15	0.47	0.50	0.41	0.34
Varieties										
V_1, 'Kufri Bahar'	1.46	9.66	11.5	12.1	13.4	0.46	1.40	2.94	3.61	1.62
V_2, 'Kufri Pushkar'	1.94	10.8	13.6	14.1	14.9	0.76	1.72	3.71	4.24	2.11
V_3, 'Kufri Surya'	1.13	8.73	10.1	11.1	11.4	0.29	1.07	2.07	2.79	1.28
SEm±	0.12	0.27	0.26	0.51	0.34	0.05	0.10	0.10	0.09	0.09
CD (P=0.05)	0.35	0.80	0.78	NS	1.01	0.15	0.29	0.31	0.27	0.25

*NS, Treatment difference not significant

maximum values of these parameters were observed in D_2 which was significantly superior to D_1 but remained statistically at par with D_3 during both the years. The effect of planting dates with varieties revealed that, crop sown on 22 October (D_2, 11.7) resulted in the highest (numbers of tubers per plant) followed by D_1 (11.1), D_3 (9.46) and D_4 (8.89). It reduced significantly with the delay in sowing at different sowing environment. Among the varieties, higher numbers of tubers/plant were recorded at Kufri Pushkar (12.3) followed by 'Kufri Bahar' (10.4) and 'Kufri Surya' (8.13) at harvesting. The variation in tubers/plant was significant among the varieties. The planting of crop on 22 October recorded the highest tuber weight (139 g/tuber) as compared to the other dates; the tuber weight was significantly higher than recorded under D_3 and D_4. However, it was on a par with D_2 (Table 3). Among the varieties, 'Kufri Pushkar' (131 g/tuber) attained the highest tuber weight as compared to 'Kufri Bahar' (118 g/tuber) and 'Kufri Surya' (110 g/tuber). The tuber weight of 'Kufri Pushkar' was significantly higher than 'Kufri Surya' and statistically at par with 'Kufri Bahar'. The differences in tuber weight of 'Kufri Surya' and 'Kufri Bahar' was also non-significant. Maximum tuber yield/plant was recorded in D_2 (637 g) as compared to the other dates and lowest in D_4 (323 g) (Table 3). 'Kufri Pushkar' had significant higher tuber yield/plant (577 g) than 'Kufri Bahar' (474 g) and 'Kufri Surya' (489 g).

The crop sown on (D_2, 22 October) gave significantly the highest tuber and biological yield (21.9 tonnes/ha and 38.1 tonnes/ha) as compared to crops sown on other dates and it was lowest in crop sown in D_4 (23 November) being 16.5 tonnes/ha and 34.7 tonnes/ha. While analysis, 'Kufri Pushkar' had significant higher tuber yield (23.2 tonnes/ha and 41.5 tonnes/ha) as compared to 'Kufri Bahar' (18.0 tonnes/ha and 35.4 tonnes/ha) and 'Kufri Surya' (16.6 tonnes/ha and 33.1 tonnes/ha) during the 2016-17 and 2017-18 (Table 3). The tuber and biological yields among all the varieties differed significantly. The D_2 sown crop recorded the highest harvest index (58.1) as compared to D_1, D_3 and D_4 during the crop season 2016-17 and 2017-18 (Table 3). 'Kufri Pushkar' (56.2) had significantly higher harvest index as compared to 'Kufri Bahar' and' Kufri Surya' during 2016-17 and 2017-18. Thongam *et al*. (2017) also reported that, tubers/plant, tuber weight, tuber yield of potato were more in October 10 planting dates as compared to the other dates in Maharashtra region. Our results confirm the findings of Dua *et al*. (2021) and Kumar *et al*. (2015) in potato crop. Planting time and varieties influenced the yield and yield attributes significantly in the forms of delayed sowing of potato with promising varieties leads to reduction in size and quality of tubers.

Table 3. Effect of planting dates on dry matter accumulation at various phenophases and yield and yield attributes of potato (pooled data of 2 years)

Treatment	Dry-matter (g/plant)					Yield and yield attributes					
	Emergence	Stolonization	Tuber initiation	Tuber bulking	Physiological maturity	No of tubers/ plant	Tuber weight (g/tuber)	Tuber yield/plant (g)	Tuber yield (tonnes/ha)	Biological yield (tonnes/ha)	Harvest index (%)
Date of planting											
D_1, 8 October	1.54	9.99	11.8	12.8	13.6	11.1	129	585	20.2	36.5	55.9
D_2, 22 October	2.53	11.4	14.8	15.8	16.1	11.6	139	637	21.9	38.02	58.1
D_3, 4 November	1.24	9.25	10.8	11.7	12.4	9.46	116	509	18.6	35.5	52.6
D_4, 15 November	0.72	8.28	9.60	10.2	10.8	8.88	95.0	323	16.5	34.7	47.4
SEm±	0.16	0.37	0.68	0.52	0.32	0.26	4.21	44	0.58	0.83	0.94
CD (P=0.05)	0.53	1.22	2.22	1.69	1.05	0.85	13.6	13	1.90	2.70	2.94
Varieties											
V_1, 'Kufri Bahar'	1.46	9.66	11.5	12.1	13.4	10.4	118	474	18.0	35.4	51.5
V_2, 'Kufri Pushkar'	1.94	10.8	13.6	14.1	14.9	12.2	131	577	23.2	41.5	56.2
V_3, 'Kufri Surya'	1.13	8.73	10.1	11.1	11.4	8.13	110	489	16.6	33.1	49.9
SEm±	0.12	0.27	0.26	0.51	0.34	0.28	2.86	17.5	0.42	0.79	0.96
CD (P=0.05)	0.35	0.80	0.78	NS	1.01	0.82	8.42	NS	1.26	2.32	2.88

*NS, Treatment difference not significant

Table 4. Pooled data of two years correlation coefficient between weather variables and growth and its yield parameters of potato

Weather variable	Plant height	Leaves/ plant	Stems/ hill	Leaf area index	Dry-matter accumulation	Tuber yield	Biological yield
Tmax	-0.46	-0.52*	-0.27	-0.54*	-0.36	0.55	0.38
Tmin	-0.35	-0.67*	-0.72*	-0.62*	-0.28	0.62**	0.45
RHm	0.24	0.35	0.36	0.50	-0.34	0.42	0.57
RHe	0.71	0.53	0.55	0.59*	0.00	0.72*	0.33
WS	0.61*	0.56*	-0.60	0.41	0.63*	-0.56*	0.72*
SSH	0.21	-0.56	0.34	-0.26	0.38	-0.85**	0.40
PE	0.14	-0.19	0.26	-0.45	0.29	0.48	0.37
Rainfall	0.46*	0.47	0.83**	0.44	0.45	0.80*	0.62*
RD	0.35*	0.42	0.78*	0.39	0.44*	0.50	0.77*

*significant at P=0.05, **significant at P=0.01

Tmax, maximum temperature; Tmin, minimum temperature; RHm, morning relative humidity; RHe, evening relative humidity; WS, wind speed; BSS, bright sunshine hours; Evap, rate of evaporation and RD, rainy day

Correlation

The plant height was significant positively correlated with wind speed, rainfall and rainy days, whereas other weather parameters negatively. The vegetative growth does not prefer higher temperatures, as the number of leaves/ plant was significant negatively correlated with maximum and minimum temperatures, whereas significantly positive with wind speed (Table 4). The number of stems/hill showed significantly positive correlation with rainfall and rainy days. Leaf area index was significantly negatively correlated with maximum and minimum temperature, wind speed, rainfall and rainy day, while other weather parameters was positively correlated with leaf area index (Table 4). The accumulation of dry matter showed significant positive correlation with wind speed and rainy days. The well-distributed rain favoured the dry-matter accumulation. Tuber yield was significantly positively correlated with minimum temperature, evening relative humidity and rainfall, whereas it was negatively correlated with wind speed and sunshine hours. The biological yield was significantly positively correlated with wind speed, rainfall and rainy day, whereas it was negatively with wind speed and sunshine hours.

It was concluded that in 22 October planting resulted in higher tuber yield as compared to planting in November. Among the treatments, 22 October observed highest tuber (21.90 tonnes/ha) and haulm yields (38.02 tonnes/ha) because it produced more plant height; more number of leaves per plant hence it produced more LAI, biomass accumulation then ultimately produced maximum tuber and haulm yield and further significantly improved yield attributes as compared to crop sown on other dates. While, among the varieties, 'Kufri Pushkar' produced highest tuber yield with improved yield attributes as compared to 'Kufri Bahar' and 'Kufri Surya'. Plant height, dry-matter accumulation and biological yield were positively correlated with wind speed, rainfall and rainy days. The number of leaves/plant and LAI was significantly negatively correlated with maximum and minimum temperatures whereas it showed significant positive correlations with wind speed. Evening relative humidity was also positively correlated with LAI and tuber yield of potato. Research should also be further strengthened to develop agronomic adaptation including rescheduling of plating dates for potato cultivation as a strategy for meeting the challenges posed by the climate change.

REFERENCES

Adane, H., Meuwissen, M.P.M., Tesfaye, A., Lommen, W.J.M., Lansink, A.O., Tsegaye, A. and Struik, P.C. 2010. Analysis of seed potato systems in Ethiopia. *Journal of American Potato Research* **87**: 537–552.

DES. 2021. Agricultural Statistics at a Glance 2021, (Directorate of Economics and Statistics). Department of Agriculture & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi.

Dua, V.K., Kapoor, T., Pathania, R. and Chauhan, S. 2021. Forecasting the impact of climate change on potato (*Solanum tuberosum* L.) productivity in Gujarat and relative adaptation strategies. *Indian Journal of Agronomy* **66**(2): 207–215.

Haverkort, A.J., Verhagen, A., Grashoff, A.C. and Uithol, P.W.J. 2004. Potato-zoning: a decision support system on expanding the potato industry through agro-ecological zoning using the LINTUL simulation approach. Decision support systems in potato production: bringing models to practice. Wageningen Academic, Wageningen, The Netherlands, pp. 29–44.

Jansky, S., Navarre, R. and Bamberg, J. 2019. Introduction to the special issue on the nutritional value of potato. *Potato Research* **96**: 95–97.

Kumar, P., Singh, S., Kumar, R., Rawal, S. and Singh, B.P. 2015. Effect of tuber planting depth on yield, quality and profitability of potato (*Solanum tuberosum* L.) processing varieties. *Indian Journal of Agronomy* **60**(1): 139–144.

Modisane, P.C. 2007. Yield and quality of potatoes as influenced by calcium nutrition, temperature and humidity. M.Sc. Thesis, University of Pretoria, South Africa.

Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C. and Pannu, R.S. 1998. Statistical software package for agricultural research workers. Recent Advances in information theory, Statistics & Computer Applications by Hooda, D.S. and Hasija, R.C., Department of Mathematics Statistics, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, pp 139–43.

Thongam, B., Kadam, A.S., Singh A.A and Singh, Y.S. 2017. Influence of planting dates on growth and yield of potato (*Solanum tuberosum* L.). *Journal of Pharmacognosy and Phytochemistry* **6**(6): 1,243–1,246.

Indian Journal of Agronomy **68** (4): 420–425 (December 2023)

Research Communication

Influence of rice straw incorporation and integrated nutrient management on growth, yield, and nutrient uptake in potato (*Solanum tuberosum*) and onion (*Allium cepa*) under rice (*Oryza sativa*)–potato-onion cropping system

REETIKA[1], JAGMOHAN KAUR[2], THAKAR SINGH[3] AND K.S. SAINI[4]

Punjab Agricultural University, Ludhiana, Punjab 141 004

Received: February 2021; Revised accepted: October 2023

ABSTRACT

A field experiment was conducted during 2019–20 at the Punjab Agricultural University, Ludhiana, to study the influence of rice (*Oryza sativa* L.) straw incorporation and integrated nutrient management on growth, yield and nutrient uptake of potato and onion (*Allium cepa* L.) in direct-seeded rice (DSR)-potato (*Solanum tuberosum* L.)–onion cropping system. The experiment was laid out in a split-plot design, consisting of 4 rice residue and nutrient-application treatments in potato in main plots and 4 nutrient application treatments in onion in subplots, replicated 4 times. Results showed that, growth and yield-attributing characters of potato increased significantly with the incorporation of rice residue and application of FYM. Tuber yield (34.0 t/ha) as well as nutrient uptake was significantly higher when rice residue was incorporated with 100% recommended dose of fertilizer (RDF) + 50 t/ha FYM in potato. Growth and yield attributes of onion were significantly higher with the application of 100% (RDF) + 50 t/ha FYM along with the incorporation of rice residue in preceding potato and among the nutrient application treatments in onion, 100% RDF + 50 t/ha FYM treatment was significantly superior to rest of the treatments. Significantly higher bulb yield was also obtained under these treatments. The interaction between rice residue and nutrient-management treatments in potato and nutrient-application treatments in onion was significant for bulb yield of onion, which was significantly higher with the combination of 100% RDF + 50 t/ha FYM treatment in onion when rice residue was incorporated with 100% RDF + 50 t/ha FYM in preceding potato (35.8 t/ha) than all other treatment combinations, but it was statistically at par with the application of 100% RDF alone in onion when preceding potato received the same level of nutrients. Thus, in DSR-potato–onion cropping system, 50 t FYM/ha could be saved in onion crop when previous potato crop was supplied with 100% RDF + 50 t/ha FYM along with rice–residue incorporation without any yield reduction.

***Key words*:** Nutrient uptake, INM, Onion, Potato, Residue management

Rice (*Oryza sativa* L.) is a dominant staple food crop in India and rice-based cropping systems are source of livelihood for about 50 million households. Nowadays, direct-seeded rice (DSR) is fast replacing transplanted rice, the continuous adoption of which has led to destruction of soil aggregates, reduction of subsurface-layer permeability and hard-pan formation (Sharma *et al*., 2003). Since vegetables like potato (*Solanum tuberosum* L.) and onion (*Allium cepa* L.) enhance the profitability of the cereal-based cropping systems (Saini *et al*., 2020; Rajpoot *et al*., 2021), the predominant rice–wheat (*Triticum aestivum* L.) cropping system in North-West India can be diversified by inclusion of these crops, which can prove fruitful not only for the land but also the growers. Inorganic chemical fertilizers are an integral part of modern agricultural systems but their excessive use deteriorates the soil and do not necessarily benefit the crop. Potato, being a short-duration crop, does not utilize the applied nutrients fully and leaves a substantial residual effect on subsequent crops like onion (Singh *et al*., 2010). Of late, management of rice straw has also gained importance owing to the large-scale production of straw annually and loss of nutrients and environmental pollution due to burning of the straw. *In-situ* management of straw includes either mulching or incorporation. Residue incorporation results in improvement of aggregate stability (Keller *et al*., 2007), enhanced water-holding capacity, infiltration and water availability (Jemai *et al*., 2013; Harish

Based on a part of M.Sc. Thesis of the first author submitted to Punjab Agricultural University, Ludhiana, Punjab in 2021 (Unpublished)

[2]**Corresponding author's Email:** kaurjagmohan@pau.edu
[1]M.Sc. Student, [2]Senior Agronomist, [3,4]Principal Agronomist, Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab 141 004

et al., 2022) besides improvement in carbon sequestration, soil organic matter (SOM) content and soil fertility, when practiced on long-term basis. In the present agricultural scenario, integrated nutrient management (INM) in DSR-based diversified cropping system is quintessential for sustaining the productivity of crops as well as fertility of land. Thus, current investigation was carried out with the objective of studying the influence of rice straw incorporation and integrated nutrient management on growth, yield and nutrient uptake of potato and onion under DSR-potato–onion cropping system.

The experiment was conducted during 2019–20 at the Punjab Agricultural University, Ludhiana (30° 54' N, 75° 48' E, 247 m above mean sea-level). The soil at the experimental site was sandy loam, low in available N (252 kg/ha), while medium in available P (20 kg/ha) and available K (171 kg/ha). During the potato-growing season (2019–20), weekly mean maximum and minimum temperature fluctuated between 10.4 and 30.5°C and 5.5 and 16.2°C, respectively, and weekly mean relative humidity ranged from 60.0 to 84.0%. While during the onion-growing season (2020), weekly mean maximum and minimum temperature ranged from 17.5 to 35.5°C and 4.9 to 21.8°C, respectively, and weekly mean relative humidity varied from 48.0 to 77.0%. The rainfall during potato- growth period (2019–20) and onion-growth period (2020) was 115.4 mm and 119.8 mm, respectively. The experiment was laid out with 4 nutrient application treatments in potato crop, viz. rice residue removal with 100% recommended dose of fertilizer (RDF); rice-residue removal with 100% RDF+ 50 t/ha FYM; rice-residue incorporation with 100% RDF and rice-residue incorporation with 100% RDF + 50 t/ha FYM, in the main plots and 4 nutrient application treatments in onion crop, viz.75% RDF; 75% RDF+ 50 t/ha FYM; 100% RDF and 100% RDF + 50 t/ha FYM, in the subplots (RDF for potato - 187.5 kg N/ha + 62.5 kg P_2O_5/ha + 62.5 kg K_2O/ha and onion - 100 kg N/ha + 50 kg P_2O_5/ha + 50 kg K_2O/ha). The experiment was conducted in a split-plot design with 4 replications.

Potato tubers of variety '*Kufri Pukhraj*' were planted manually on ridges prepared with the tractor mounted ridger at a spacing of 60 cm × 20 cm on 25 October 2019 using 4.5 t seed tubers/ha. Whole straw load (7.6 t/ha) was incorporated in the residue-incorporation treatments, while whole straw was removed in residue-removal treatments. Onion nursery for the variety '*Punjab Naroya*' was sown on 2 November 2019 in lines 5 cm apart on beds using 10 kg seed/ha. Transplanting of the nursery was done on 24 January 2020 on the beds maintaining row-to-row spacing of 15 cm, while plant-to-plant distance was kept at 7.5 cm. All the recommended agronomic practices such as fertilizer application, weed management, pest and disease management were followed for potato and onion crops. For growth and yield attributes, 5 random plants were selected from each plot for both potato and onion. Nutrient uptake of potato (tuber + haulm) and onion (bulb) was worked out from their respective nutrient content and yield on dry-weight basis (Rana *et al*., 2014). Rice-equivalent yield (system productivity) and net returns (gross returns-cost of cultivation) were calculated by using the prevailing prices of various inputs and outputs. Statistical analysis of the data recorded in onion was carried out using analysis of variance technique as applicable to split-plot design. The difference between the treatment means were tested as to their statistical significance with appropriate critical difference (CD) value at 5% level of probability.

Results revealed that, rice-residue incorporation and integrated nutrient management had a significant influence on the growth characters of potato (Table 1). Emergence was the highest (93.5%) when rice residue was incorporated along with application of 100% RDF + 50 t/ha FYM in potato. The maximum plant height (46.7 cm), dry-matter accumulation (68.5 g/plant) and leaf-area index (LAI, 3.35) at haulm cutting were recorded under rice-residue incorporation with 100% RDF+ 50 t/ha FYM treatment. The increase in growth parameters might be attributed to the increased availability of nutrients and enhanced organic carbon content and activity of beneficial micro-organisms. It might also have synthesized growth-promoting substances that led to increased meristematic activity promoting rapid initiation and boost in plant height thereby, increasing the dry-matter accumulation because of the enhanced rate of photosynthesis and translocation of photosynthates from source to sink (Koroto, 2019; Varatharajan *et al*., 2022).

The yield attributes, viz. tuber yield/plant (547.8 g) and tuber number/plant (13.8) were also significantly higher with the application of 100% RDF + 50 t/ha FYM along with rice residue incorporation (Table 1). Total tuber yield increased significantly by 34.9% under rice-residue incorporation with 100% RDF + 50 t/ha FYM treatment over 100% RDF alone. Integration of 50 t/ha FYM and 100% RDF along with rice-residue incorporation resulted in 9.3% higher yield of potato than 100% RDF + 50 t/ha FYM without residue incorporation, thus indicating the beneficial effect of incorporating rice-residue. Similar trend was followed by haulm yield, which was maximum under rice residue incorporation with 100% RDF + 50 t/ha FYM treatment (12.2 t/ha). Significantly higher total N, P and K uptake by potato was recorded with the same treatment. The probable reason for increment in nutrient uptake might be attributed to augmented supply of nutrients that leads to increased tuber and haulm yields owing to favourable impact of concurrent use of organic manures with fertilizers

Table 1. Effect of rice-residue and nutrient-application treatments in potato on growth, yield attributes and yield, and nutrient uptake of potato

Treatment	Plant height (cm)			Dry-matter accumulation (g/plant)	LAI	Tuber yield/ plant (g)	Tubers/ plant	Tuber yield (t/ha)	Haulm yield (t/ha)	Total nutrient uptake (kg/ha)		
	30 DAS	60 DAS	At haulm cutting							N	P	K
Rice-residue removal with 100% RDF (NPK)	15.4	32.3	32.8	51.8	2.12	367.0	8.55	25.2	9.79	82.0	21.5	97.4
Rice-residue removal with 100% RDF (NPK) + FYM 50 t/ha	18.9	37.2	39.2	63.0	3.15	469.3	11.5	31.1	11.2	106.2	28.6	132.8
Rice-residue incorporation with 100% RDF (NPK)	18.1	35.8	38.7	61.6	3.08	446.8	10.7	30.2	10.9	102.2	27.4	127.5
Rice-residue incorporation with 100% RDF (NPK) + FYM 50 t/ha	21.9	42.4	46.7	68.5	3.35	547.8	13.8	34.0	12.2	124.6	34.6	155.6
SEm±	0.67	0.68	0.80	1.63	0.06	23.6	0.66	0.85	0.19	2.61	0.67	2.71
CD (P=0.05)	2.16	2.18	2.55	5.20	0.19	75.6	2.11	2.72	0.62	8.35	2.15	8.67

LAI, Leaf-area index, RDF, recommended dose of fertilizer

on the plant height, leaf area, dry-matter production and its partitioning within the plant parts (Babu, 2019).

The growth and yield attributes of onion, viz. plant height, leaves/plant, bulb diameter and bulb weight at maturity were significantly higher under rice-residue incorporation with 100% RDF + 50 t/ha FYM treatment in preceding potato than rest of the treatments. Among the nutrient application treatments in onion, an application of 100% RDF+ 50 t/ha FYM in onion resulted in significantly higher growth and yield attributes in onion. Gererufael *et al*. (2020) also found increase in bulb diameter and bulb weight with integration of organic and inorganic nutrient sources.

Bulb yield of onion was significantly influenced by rice-residue and nutrient- management treatments in both potato and onion and their interaction. Among the nutrient- management treatments in preceding potato, an application of 100% RDF + 50 t/ha FYM with rice-residue incorporation resulted in 22.8% higher bulb yield than the application of 100% RDF alone without residue. Application of 100% RDF + 50 t/ha FYM in onion resulted in enhancement in bulb yield by 21.5% over sole application of 75% RDF and 7.8% over application of 100% RDF. Rice residue and nutrient application in potato × nutrient application in onion interaction (Table 3) revealed that, bulb yield of onion (35.8 t/ha) was significantly higher under the application of 100% RDF + 50 t/ha FYM in onion when preceding potato received the application of 100% RDF + 50 t/ha FYM along with incorporation of rice residue as compared to other treatment combinations but remained statistically at par with the 100% RDF treatment in onion when preceding potato was supplied with same level of nutrients (34.7 t/ha). Nutrient uptake by bulbs showed the similar trend as the bulb yield since, it is the product of nutrient content and yield on dry- weight basis (Table 2). Increase in bulb yield with rice-residue incorporation and FYM treatments is attributed largely to increased biomass input that enriched the soil quality in terms of biotic activity and organic carbon content (Rajpoot *et al*., 2021) that might have led to increased porosity and improved root proliferation. Also, the growth characters, viz. plant height, bulb weight and bulb diameter, are known to increase the crop yield (Nasreen *et al*., 2007).

Rice-equivalent yield of the system (39.2 t/ha) was significantly higher with the application of 100% RDF + 50 t/ha FYM to onion where preceding potato crop was supplied with 100% RDF, FYM and rice-residue incorporation (Table 4) which was statistically at par with 100% RDF application in onion when preceding potato crop was supplied with 100% RDF and FYM along with rice-residue incorporation (38.6 t/ha). Among the various combinations of nutrient application in potato and onion, significantly

Table 2. Effect of rice-residue and nutrient-application in preceding potato and nutrient application in onion on plant height, leaves/plant, bulb diameter, bulb weight and nutrient uptake in bulbs at maturity in onion

Treatment	Plant height (cm)	Leaves/ plant	Bulb diameter (cm)	Bulb weight (g)	Bulb yield (t/ha)	Nutrient uptake (kg/ha)		
						N	P	K
Rice-residue and nutrient-application in preceding potato								
Rice-residue removal with 100% RDF (NPK)	63.7	5.47	3.94	45.6	27.6	93.5	4.71	75.4
Rice-residue removal with 100% RDF (NPK) + FYM 50 t/ha	69.9	6.68	4.42	62.1	31.0	108.2	6.47	92.3
Rice-residue incorporation with 100% RDF (NPK)	68.8	6.44	4.29	60.1	30.2	104.9	6.03	87.7
Rice-residue incorporation with 100% RDF (NPK) + FYM 50 t/ha	75.3	8.07	4.94	71.9	33.9	120.7	7.89	109.2
SEm±	0.46	0.08	0.07	0.76	0.40	1.46	0.16	1.47
CD (P=0.05)	1.46	0.26	0.22	2.43	1.26	4.69	0.53	4.71
Nutrient-application in onion								
75% RDF (NPK)	63.5	5.39	3.90	48.0	27.4	93.1	4.60	74.2
75% RDF (NPK) + FYM 50 t/ha	70.4	6.73	4.40	61.7	31.1	108.4	6.45	93.5
100% RDF (NPK)	69.9	6.75	4.40	61.7	30.9	107.4	6.35	92.1
100% RDF (NPK) + FYM 50 t/ha	74.0	7.80	4.89	68.4	33.3	118.3	7.70	104.8
SEm±	0.43	0.12	0.05	0.84	0.24	1.43	0.14	1.01
CD (P=0.05)	1.22	0.34	0.14	2.40	0.70	2.71	0.40	2.89

RDF, recommended dose of fertilizer

Table 3. Interactive effect of rice-residue and nutrient-application in preceding potato and nutrient-application in onion on bulb yield (t/ha) of onion

Rice-residue and nutrient-application in preceding potato	Nutrient-application in onion				Mean
	75% RDF (NPK)	75% RDF (NPK) + FYM 50 t/ha	100% RDF (NPK)	100% RDF (NPK) + FYM 50 t/ha	
Rice-residue removal with 100% RDF (NPK)	24.6	27.7	26.8	31.2	27.6
Rice residue removal with 100% RDF (NPK) + FYM 50 t/ha	27.2	31.2	31.6	34.0	31.0
Rice-residue incorporation with 100% RDF (NPK)	26.9	31.4	30.4	32.3	30.2
Rice-residue incorporation with 100% RDF (NPK) + FYM 50 t/ha	31.1	34.0	34.7	35.8	33.9
Mean	27.4	31.1	30.9	33.3	
SEm±			0.49		
CD (P=0.05)			1.41		

higher net returns (431.8×10^3 ₹/ha) were obtained with 100% RDF application in onion when the previous potato crop was supplied with 100% RDF, FYM along with rice-residue incorporation (Table 5) and was found to be statistically at par with the application of 100% RDF + FYM 50 t/ha where preceding potato crop received the application of 100% RDF + FYM 50 t/ha along with rice-residue incorporation (426.5×10^3 ₹/ha).

Based on the present study, it can be concluded that in DSR–potato–onion cropping system, the highest bulb yield of onion (35.8 t/ha) was obtained with application of 100% RDF and 50 t/ha FYM which remained statistically at par with 100% RDF, when previous potato crop was supplied with 50 t/ha FYM and 100% RDF along with rice–residue incorporation. Thus, rice–residue incorporation along with 50 t FYM/ha and 100% RDF applied to previous potato crop is sufficient for the following onion crop with sole application of 100% RDF without any yield reduction.

REFERENCES

Babu, M.Y.N. 2019. Response of potato (*Solanum tuberosum* L.) to integrated nutrient management. M.Sc. Thesis, Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India (unpublished).

Gererufael, L.A., Abraham, N.T. and Reda, T.B. 2020. Growth and yield of onion (*Allium cepa* L.) as affected by farmyard manure and nitrogen fertilizer application in Tahtay Koraro District, Northwestern Zone of Tigray, Ethipoia. *Vegetos* **33**: 617–627.

Table 4. Effect of rice-residue and nutrient-application in potato and nutrient-application in onion on rice-equivalent yield (t/ha)

Rice residue and nutrient-application in preceding potato	Nutrient-application in onion				Mean
	75% RDF (NPK)	75% RDF (NPK) + FYM 50 t/ha	100% RDF (NPK)	100% RDF (NPK) + FYM 50 t/ha	
Rice-residue removal with 100% RDF (NPK)	29.7	31.3	30.8	33.0	31.2
Rice-residue removal with 100% RDF (NPK) + FYM 50 t/ha	33.6	35.6	35.8	37.0	35.5
Rice-residue incorporation with 100% RDF (NPK)	33.0	35.3	34.8	35.7	34.7
Rice-residue incorporation with 100% RDF (NPK) + FYM 50 t/ha	36.8	38.3	38.6	39.2	38.2
Mean	33.3	35.1	35.0	36.2	
SEm±	Rice-residue and nutrient-application treatments in potato : 0.5 Nutrient-application in onion : 0.12 Interaction : 0.23				
CD (P=0.05)	Rice-residue and nutrient-application treatments in potato : 1.5 Nutrient-application in onion : 0.35 Interaction : 0.70				

Selling price, DSR, 18,150 ₹/t; potato, 8,000 ₹/t; onion, 9,000 ₹/t
RDF, Recommended dose of fertilizer

Table 5. Effect of rice-residue and nutrient-application in potato and nutrient-application in onion on net returns ($\times 10^3$ ₹/ha) of the system

Rice-residue and nutrient-application in preceding potato	Nutrient-application in onion				Mean
	75% RDF (NPK)	75% RDF (NPK) + FYM 50 t/ha	100% RDF (NPK)	100% RDF (NPK) + FYM 50 t/ha	
Rice-residue removal with 100% RDF (NPK)	287.4	300.9	305.7	330.4	306.1
Rice-residue removal with 100% RDF (NPK) + FYM 50 t/ha	344.9	366.1	382.6	389.5	370.8
Rice-residue incorporation with 100% RDF (NPK)	344.9	371.4	375.1	378.0	367.3
Rice-residue incorporation with 100% RDF (NPK) + FYM 50 t/ha	400.1	412.1	431.8	426.5	417.6
Mean	344.3	362.6	373.8	381.1	
SEm±	Rice-residue and nutrient-application treatments in potato : 8.87 Nutrient-application in onion : 2.11 Interaction : 4.23				
CD (P=0.05) for interaction	Rice residue and nutrient-application treatments in potato : 26.6 Nutrient-application in onion : 6.33 Interaction : 12.7				

RDF, recommended dose of fertilizer

Harish, M.N., Choudhary, A.K., Bhupenchandra, I., Dass, A., Rajanna, G.A., Singh, V.K., Bana, R.S., Varatharajan, T., Verma, P., George, S., Kashinath, G.T., Bhavya, M., Chongtham, S.K., Devi, E.L., Kumar, S., Devi, S.H. and Bhutia, T.L. 2022. Double zero-tillage and foliar-P nutrition coupled with bio-inoculants enhance physiological photosynthetic characteristics and resilience to nutritional and environmental stresses in maize–wheat rotation. *Frontiers in Plant Science* **13**: 959541.

Jemai, I., Ben Aissa, N., Ben Guirat, S., Ben-Hammouda, M. and Gallali, T. 2013. Impact of three and seven years of no-tillage on the soil water storage, in the plant root zone, under a dry sub humid Tunisian climate. *Soil and Tillage Research* **126**: 26–33.

Keller, T., Arvidsson, J. and Dexter, A. 2007. Soil structures produced by tillage as affected by soil water content and the physical quality of soil. *Soil and Tillage Research* **92**: 45–52.

Koroto, S. 2019. Effect of farmyard manure and mineral NP fertilizers on yield related traits and yield of potato (*Solanum tuberosum* L.) at Areka, Southern Ethiopia. *International Journal of Horticultural Science and Ornamental Plants* **5**: 74–85.

Nasreen, S., Haque, M.M., Hossain, M.A. and Farid, A.T.M. 2007. Nutrient uptake and yield of onion as influenced by nitrogen and sulphur fertilization. *Bangladesh Journal of Agricultural Research* **32**: 413–420.

Rajpoot, S.K., Rana, D.S. and Choudhary, A.K. 2021. Crop and water productivity, energy auditing, carbon footprints and soil health indicators of Bt-cotton transplanting led system intensification. *Journal of Environmental Management* **300**: 113732.

Rana, K.S., Choudhary, A.K., Sepat, S., Bana, R.S. and Dass, A. 2014. *Methodological and Analytical Agronomy,* pp. 276. Post Graduate School, ICAR-Indian Agricultural Research

Institute, New Delhi, India.

Saini, K.S., Kaur, J., Singh, T., Chahal, T.S. and Manhas, S.S. 2020. Productivity, economics and energetics of potato (*Solanum tuberosum*)-based systems as an alternative to rice (*Oryza sativa*)–wheat (*Triticum aestivum*) in *Doaba* region of Punjab. *Indian Journal of Agronomy* **65**(1): 125–129.

Sharma, P.K., Ladha, J.K. and Bhushan, L. 2003. Soil physical effects of puddling in rice-wheat cropping systems. (In:) *Improving the Productivity and Sustainability of Rice–Wheat Systems: Issues and Impacts,* pp. 97–113. (Ladha, J.K., Hill, J.E., Duxbury, J.M., Gupta, R.K. and Buresh, R.J. (Eds).

Singh, S.N., Sah, A.K., Singh, R.K., Singh, V.K. and Hassan, S.S. 2010. Diversification of rice (*Oryza sativa* L.)-based cropping sequences for higher production potentials and economic returns in India's central Uttar Pradesh. *Journal of Sustainable Agriculture* **34**: 141–152.

Varatharajan, T., Dass, A., Choudhary, A.K., Sudhishri, S., Pooniya, V., Das, T.K., Rajanna, G.A., Prasad, S., Swarnalakshmi, K., Harish, M.N., Dhar, S., Singh, R., Raj, R., Kumari, K., Singh, A., Sachin, K.S. and Kumar, P. 2022. Integrated management enhances crop physiology and final yield in maize intercropped with blackgram in semiarid South Asia. *Frontiers in Plant Science* **13**: 975569.

Indian Journal of Agronomy **68** (4): 426–429 (December 2023)

Research Communication

Effect of 2, 4-D SODIUM SALT on weeds, growth and yields in *rabi* maize (*Zea mays* L.)

SHIVAM KUMAR[1], PRATIK SANODIYA[2], A K JHA[3], M.P. SAHU[4] AND BADAL VERMA[5]

Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 221 005, Uttar Pradesh, India

Received: December 2022; Revised accepted: November 2023

ABSTRACT

A field investigation was conducted during winter (*rabi*) season of 2021 at Agricultural Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, to study the efficacy of doses of 2, 4-D sodium salt 80% WP on weeds, productivity and economics of *rabi* maize (*Zea mays* L.). Application of 2, 4-D sodium salt 80% WP @ 1,250 g/ha at 25 days after sowing (DAS) resulted in to lesser weed density and weed dry weight of *Physalis minima* Roem. & Schult, *Chenopodium album* (L.), *Melilotus indicus* (L.) and *Cichorium intybus* (L.) as compared to 2, 4-D sodium salt 80% WP @ 1,000 g/ha and 2, 4-D sodium salt 80% WP @ 750 g/ha at 60 DAS, with higher weed control efficiency (77.3 %) and lesser weed index (34.9 %). At 60 DAS, 2, 4-D sodium salt 80% WP (applied @1250 g/ha at 25 DAS) produced higher plant height, number of leaves, chlorophyll content, leaf area index and plant dry-matter over other treatments except weed free and two hand weeding at 20 and 40 DAS. Application of 2, 4-D sodium salt 80% WP @ 1,250 g/ha at 25 DAS recorded higher number of cobs, number of kernels, number of kernels/row and seed index as compared to 2, 4-D sodium salt 80% WP @ 1,000 g/ha, and 2, 4-D sodium salt 80% WP @ 750 g/ha. Higher kernel (3.7 t/ha) and stover yield (4.7 t/ha) of maize was recorded due to application of 2, 4-D sodium salt 80% WP @ 1,250 g/ha at 25 DAS with higher harvest index (44.5%) and monetary returns (62.5 × 10^3 ₹/ha) as compared to 2, 4-D sodium salt 80% WP @ 1,000 g/ha, and 2, 4-D sodium salt 80% WP @ 750 g/ha.

Key words: 2, 4-D, Economics, Grain and stover yields, Weed-control efficiency, Weed index

Maize is grown over more than193 million ha of land in 170 countries with a production of 1147.7 million tonnes and on a larger range of soil, biodiversity, climates under different management systems (FAOSTATE, 2020). In India, however, maize productivity is just half (2.96 t/ha) than the average productivity of the rest of the world (Anonymous, 2020). After rice and wheat, maize is India's third most significant cereal crop. Recently in India, there is an increasing interest to promote non-rice crops such as maize that requires less water during the dry season to enhance food production and generate more income for farmers (Sarangi *et al*., 2020). It can be produced in a variety of climates, ranging from extreme semi-arid to sub-humid and humid, which predominantly occupies 82% area under cultivation in rainy (*kharif)* season and nearly 10% in winter (*rabi*) season (Sairam *et al.,* 2023a). Broad-leaved weeds cause harm to crops in a veriety of ways and this is because of unusual adaptation characteristics of the weeds and their regeneration ability. Therefore, weed management is the major and important part of crop production. At present we have many selective herbicides with different modes of action of weed control in maize. 2, 4 – D which kills broad leaf weeds after emergence by causing the cells in the tissues that carry water and nutrients to divide and grow without stopping (Raghuwanshi *et al.* 2023). In view of this we planned an experiment to find out the best dose of this herbicide for getting higher weed control efficiency and yields of *rabi* hybrid maize.

A field experiment was conducted during winter (*rabi*) season of 2021 at Agricultural Research Farm, of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The soil was sandy clay loam, with *p*H 7.40, low in available organic carbon (0.41%),

Based on a part of M.Sc. Thesis of the first author submitted to Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh in 2022 (unpublished)

[2]**Corresponding author's Email:** prsanodiya10@gmail.com
[1]M.Sc. Student, [2]Assistant Professor, Department of Agronomy, Institute of Agricultural Science, Banaras Hindu University, Varanasi, Uttar Pradesh 221 005; [3]Assistant Professor, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482 004; [4]Senior Research Fellow, ICAR-Directorate of Weed Research, [5]Ph.D Scholar, Department of Agronomy. Jawaharlal Nehru krishi Vishwa Vidyalaya Maharajpur, Jabalpur, Madhya Pradesh 482 004

available nitrogen (207.47 kg/ha) and medium in available phosphorous (23.85 kg/ha) and potassium (219.60 kg/ha). The experiment was laid out in a randomized block design, comprising 8 treatments; weedy, 2-hand weedings at 20 and 40 DAS, Atrazine 50% WP 1,000 g/ha as post emergence (PE), 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS. 2, 4-D sodium salt 80% WP 1,000 g/ha, 2, 4-D sodium salt 80% WP 750 g/ha and weed free replicated thrice. Maize variety 'DHM 121' which has duration of 150 days and yield potentiality of 55–60 q/ha was sown manually during the first week of December using the seed rate of 25 kg/ha and 60 × 20 cm row-row and plant-plant spacing. Application of PE herbicide was done according to the treatments using knap-sack sprayer fitted with even-fan nozzle using water @ 300 litre/ha. Species-wise weed density and their biomass were measured at 45 days after sowing (DAS) by placing a quadrate of $0.50/m^2$ randomly at two places in each plot. Data on weed density and biomass were subjected to square root transformation before analysis. The differences within the treatment means were examined by means of "Critical Difference" (CD) and mean comparison was done using "Duncan Multiple Range Test" (DMRT) test (Gomez and Gomez, 1984) with the help of software named "Statistical Package for Social Science" (SPSS) presently owned by international business machine (IBM) corporation.

The density of different weeds at 60 DAS application of herbicide as influenced by different weed control treatments were recorded (table 1). Lower density of *Physalis minima* and *Chenopodium album* were recorded in hand weeding twice at 20 and 40 DAS in comparison to atrazine 50% WP 1,000 g/ha as PE, 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS. Density was recorded lesser in 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS than 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS and both were statistically similar to each other. Density of *Melilotus indicus* and *Cichorium intybus* were found lowest in hand weeding twice at 20 and 40 DAS and atrazine 50% WP 1,000 g /ha as PE and both were statistically similar to each other. The density was observed lower in 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS in comparison to 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS, 2, 4-D and 2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS and these were recorded statistically similar with each other. The dry weight of *Physalis minima* was recorded lower in hand weeding twice at 20 and 40 DAS as compared to Atrazine 50% WP 1,000 g/ha as PE. Application of 2, 4-D sodium salt 80% WP @ 1250 g/ha at 25 DAS found lower dry

Table 1. Effect of herbicidal treatments on density, dry weight (g/), weed control efficiency and weed index of broad-leaf weeds at 60 DAS in *rabi* maize

Treatment	Weed density (No. /m^2)				Weed dry weight (g/m^2)				Weed control efficiency (%)	Weed Index (%)
	Physalis minima (L.)	*Chenopodium album* L.	*Melilotus Indicus* (L).	*Cichorium intybus* (L.)	*Physalis minima* L.	*Chenopodium album* L.	*Melilotus indicus* (L.)	*Cichorium intybus* (L.)		
Weedy	16.6 (276)	6.5 (42)	4.7 (22)	4.8 (23)	10.3 (105.7)	5.1 (25.6)	3.5 (11.8)	60 DAS	0.0	75.1
Hand weeding twice at 20 and 40 DAS	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	4.1 (16.9)	83.3	16.8
Atrazine 50% WP 1,000 g/ha as PE	1.1 (1)	0.9 (1)	0.7 (0)	0.7 (0)	0.9 (0.4)	0.7 (0.1)	0.7 (0.0)	0.7 (0.0)	80.1	28.4
2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS	2.2 (5)	3.2 (11)	1.3 (1)	1.3 (2)	1.8 (2.8)	1.6 (2.1)	0.8 (0.2)	1.1 (0.8)	70.6	58.5
2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS	1.8 (3)	2.6 (7)	1.1 (1)	0.9 (1)	1.4 (1.5)	1.5 (1.9)	0.7 (0.1)	1.2 (1.0)	74.8	43.2
2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS	1.3 (2)	1.6 (3)	0.9 (1)	0.7 (0)	1.2 (0.9)	1.4 (1.5)	0.7 (0.1)	1.1 (0.9)	77.3	34.9
Weed-free	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	100	0.0
SEm±	0.12	0.09	0.10	0.11	0.07	0.02	0.02	0.39	-	-
CD (P=0.05)	0.38	0.28	0.31	0.34	0.23	0.08	0.07	0.70	-	-

Data were subjected to square root ($\sqrt{x + 0.5}$) transformation; figures in parentheses are original values.

weight as compared to 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS. 2, 4-D sodium salt 80% WP 1000 g/ha at 25 DAS recorded lesser dry weight than 2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS. Lesser dry weight of *Chenopodium album* was reported in hand weeding twice at 20 and 40 DAS as compared to atrazine 50% WP 1,000 g/ha as PE and both were found statistically at par with each other. Dry weight was found lower in 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS in comparison of 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS and 2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS and all were found statistically similar to each other. Dry weight of *Melilotus indicus* and *Cichorium intybus* were found lowest in Atrazine 50% WP 1,000 g/ha as PE and hand weeding twice at 20 and 40 DAS and both were recorded statistically similar to each other. Dry weight was recorded lesser in 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS as compared to 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS. The application of post-emergence herbicides decreases the density of the weeds due to non-disturbance of the soil which does not allow the second flush to come out (Joshi *et al.,* 2018 and Mandi *et al.,* 2019). Amongst the different weed management treatments, the higher weed control efficiency (83.3%) was found in hand weeding twice at 20 and 40 DAS followed by atrazine 50% WP 1,000 g/ha as PE, 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS, 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS, 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS, 2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS (Table 1). This might be due to more weed killing efficiency which resulted in lower weed dry matter accumulation. Similar findings also reported in maize by Triveni *et al.,* 2017. The lower weed index (16.8%) was recorded in hand weeding twice at 20 and 40 DAS in comparison of atrazine 50% WP 1,000 g/ha as PE. Weed index was found lower in 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS as compared to 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS possessed lower weed index in comparison of 2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS (Raghuwanshi *et al*., 2023).

Higher number of leaves were recorded in 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS than 2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS and both were found statistically similar to each other. Plant height followed the trend: atrazine 50% WP 1,000 g/ha as PE *fb* hand weeding twice at 20 and 40 DAS, 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS and all were found statistically similar to each other. Plant height was increased with application of 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS followed by 2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS and all were recorded statistically at par to each other. The similar observation reported by Pasha *et al.* (2012).

Number of cobs per plant was found higher in 2, 4-D

Table 3. Effect of herbicidal treatments on number of leaves/plant, plant height, number of cobs, number of grains, number of grains/row, seed index, grain yield and economics of *rabi* maize

Treatment	Numbers of leaves/plant	Plant height (cm)	No. of cobs/plant	No. of grain rows/cob	No. of grains/row	Seed index (g)	Grain yield (t/ha)	Net return (× 10³ ₹/ha)
Weedy	7.6	21.6	2.4	10.9	22.1	30.9	1.4	57.4
Hand weeding twice at 20 and 40 DAS	11.0	25.2	3.2	15.5	31.6	36.4	4.8	74.3
Atrazine 50% WP 1,000 g/ha as PE	10.6	24.2	3.0	15.4	30.3	35.2	4.1	71.3
2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS	8.3	22.6	2.4	13.7	25.9	33.6	2.4	27.7
2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS	9.6	23.0	2.7	14.7	28.4	34.7	3.3	50.1
2, 4-D sodium salt 80% WP 1250 g/ha at 25 DAS	10.3	23.4	2.9	15.2	29.3	34.9	3.7	62.5
Weed-free	13.3	25.5	3.4	16.2	33.1	37.7	5.8	87.8
SEm±	0.37	0.41	0.06	0.29	0.65	0.36	0.83	-
CD (P=0.05)	1.14	1.25	0.20	0.90	1.98	1.11	2.54	-

sodium salt 80% WP 1,250 g/ha at 25 DAS as fallowed by to 2, 4-D sodium salt 80% WP 1,000 g/ha than others. Number of kernel rows per cobs was recorded higher in hand weeding twice at 20 and 40 DAS in comparison to atrazine 50% WP 1,000 g/ha as PE, 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS and 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS. Number of grains per row was found higher in 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS in comparison to 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS over other treatments. Seed index was recorded higher in hand weeding twice at 20 and 40 DAS in comparison to Atrazine 50% WP 1,000 g/ha as PE followed by 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS, 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS (table 4). The more weed competition might also lead to decreased seed size and thus decreased 1,000-grain weight while it increased the kernel weight in more resource available plots with the lesser crop-weed competition. The similar observation were reported by Sanodiya *et. al.* (2013). Higher kernel yield was obtained under hand weeding twice at 20 and 40 DAS followed by atrazine 50% WP 1,000 g/ha as PE, 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS, 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS and 2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS. This might be due to better growth parameters and better yield parameters i.e., number of cobs/plant, number of grain rows/cob, number of grains per row and seed index (table 4). The similar findings also reported by Sairam, *et. al.* (2023).

Amongst the different weed management treatments higher net return (74.3×10^3 ₹/ha) were obtained in hand weeding twice 20 and 40 DAS followed by atrazine 50% WP 1,000 g /ha as PE, 2, 4-D sodium salt 80% WP 1,250 g/ha at 25 DAS, 2, 4-D sodium salt 80% WP 1,000 g/ha at 25 DAS and 2, 4-D sodium salt 80% WP 750 g/ha at 25 DAS. The similar observations were reported by Sinodiya and Jha (2014).

Based on the present study it can be concluded that 2, 4-D sodium salt 80% WP @ 1,250 g/ha at 25 DAS was found effective in controlling weeds in *rabi* hybrid maize and recorded higher net return with B: C ratio of (2.67). Thus, for effective control of weeds and higher yield and nutrient uptake of *rabi* maize, this treatment can be suggested under agro-climatic conditions of Varanasi, Uttar Pradesh.

REFERENCES

Anonymous, 2020. Agricultural statistical data, Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare, Government of India.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*. John Wiley & Sons.

Joshi, N. Singh, V.P., Galav, A., Sharma, S., Dhakar, R. and Meena, R. 2018. Bio-efficacy of various doses of 2, 4-D Ethyl ester 80% EC on weed growth, crop yield of maize and the residual effect on succeeding pea crop. *International Journal of Advanced Scientific Research and Management, Special Issue* **1**(3): 7–8.

Mandi, S., Mandal, B., Krishna, S.K. and Reddy, D.D. 2019. Effect of integrated weed management on weed growth and yield of winter maize (*Zea mays*). *Indian Journal of Agronomy* **64**(3): 373–377.

Pasha, M.L., Bhadru, D., Krishna, L. and Naik, R.B.M. 2012. Evaluation of different herbicides in zero tillage maize. *Madras Agricultural Journal* **99**(7–9): 471–472.

Raghuwanshi, M., Jha, A.K., Verma, B., Yadav, P.S., and Shrivastava, A. 2023. Weed dynamics of fodder maize as influenced by different herbicides. *International Journal of Environment and Climate Change* **13**(7): 245–251.

Sairam, G., Jha, A.K., Verma, B., Porwal, M., Dubey, A., and Meshram, R.K. 2023a. Effect of mesotrione 40% SC on weed growth, yield and economics of maize (*Zea mays* L.). *International Journal of Environment and Climate Change* **13**(7): 608–616.

Sairam, G., Jha, A.K., Verma, B., Porwal, M., Sahu, M.P. and Meshram, R.K. 2023b. Effect of pre and post-emergence herbicides on weed flora of maize. *International Journal of Plant & Soil Science* **35**(11): 68–76.

Sanodiya, P., Jha, A.K. and Shrivastava, A. 2013. Effect of integrated weed management on seed yield of fodder maize. *Indian Journal of Weed Science* **45**(3): 214–216.

Sarangi, S.K., Singh, S., Srivastava, A.K., Choudhary, M., Mandal, U.K., Lama, T.D., Mahanta, K.K., Kumar, V., Sharma, P.C. and Ismail, A.M. 2020. Crop and residue management improves productivity and profitability of rice–maize system in salt-affected rainfed lowlands of East India. *Agronomy* **10**(12): 2019. https://doi.org/10.3390/agronomy 10122019

Sinodiya P, and Jha A.K. 2014. Effect of weed management control practices on nutrient uptake and soil properties in fodder maize. *JNKVV Research Journal* **48**(1): 60–63.

Triveni, U., Sandhya, R.Y., Patro, T.S.K. and Divya, M. 2017. Weed management in maize with different pre and post emergence herbicides. *Journal of Experimental Biology and Agricultural Sci*ences **5**(1): 54–58.

Indian Journal of Agronomy **68** (4): 430–433 (December 2023)

Research Communication

Effect of planting geometry and weed-management practices on yield of scented rice (*Oryza sativa*) varieties

PURNIMA HALDAR[1] AND ASHWANI KUMAR THAKUR[2]

Shaheed Gundadhur College of Agriculture and Research Station, Indira Gandhi Krishi Vishwavidhyalaya, Jagdalpur, Raipur, Chhatishgarh 494 001

Received: January 2022; Revised accepted: November 2023

ABSTRACT

A field experiment was conducted at the Shaheed Gundadhur College of Agriculture and Research Station, of the Indira Gandhi Krishi Vishwavidhyalaya, Jagdalpur, Chhattisgarh during rainy season (*Kharif*) of 2019, to evaluate the effect of planting geometry and weed-management practices in transplanted scented rice varieties. Treatments consisting combination of 2 varieties, 2 planting geometry and 4 weed management practices were replicated thrice in a split-split plot design. The dominant weeds in transplanted rice were: *Ludwigia peploides* (Kunth) P.H. Raven., *Spilanthes acmella* (L.) C.B. Clarke ex Hook. f., *Echinochloa colona* L., *Cyperus difformis* L., *Cyperus iria* L., *Commelina benghalensis* L. and *Fimbristylis miliacea* (L.) Vahl. Significantly lowest population of different weed species, and the highest grain and straw yields, and harvest index were found with variety, 'Tarunbhog Selection 1' while the maximum test weight was observed with 'Dubraj Selection 1'. The planting geometry of 20 cm × 20 cm recorded the minimum weed population and the highest yield and benefit cost ratio. Application of pyrazosulfuron ethyl 10% WP @ 20 g/ha at 3 Days after transplanting (DAT) + 1 hand weeding (HW) at 25 DAT was found the most effective for broad-spectrum weed control and increased the rice grain yield. The highest net returns and benefit cost were recorded with the pre-emergence application of pyrazosulfuron ethyl 10 % WP @ 20 g/ha.

Key words: Benefit: cost ratio, 'Dubraj selection 1', Harvest index, Planting Geometry, 'Tarunbhog Selection 1', Weed

Rice (*Oryza sativa* L.) is the most important foodgrain crop of India and a major source of energy for about 60% of the global population. Asia's food security mainly depends on the irrigated rice which contributes one-third of total rice production. About 90% rice is produced and consumed in Asian country (Basha *et al.,* 2017). Among the paddy producing countries, India has the largest acreage (43.39 million ha) and is the second largest producer (104.32 million tonnes) next to China (207 million tonnes). The productivity of rice in India is quite low 2.39 t/ha, while the world's average productivity is 4.25 t/ha. Chhattisgarh occupies an area of 3.84 million ha with production and productivity of 6.09 million tonnes and 1.5 t/ha respectively (MAFW, 2016).

Chhattisgarh is very popular for growing short slender/medium slender aromatic rice i.e. 'Dubraj', 'Tulsi Manjari', 'Badshahbhog', 'Vishnubhog', 'Gopalbhog', 'Kubrimohar', 'Laxmibhog' and 'Jawaphool'. More than 100 local landraces of scented rice with pleasing aroma are grown in different parts of the Chhattisgarh state. Among the scented rice, 'Dubraj' occupies ~10 % of the total rice growing area of the Chhattisgarh state (Sharma *et al.,* 2017).

An ideal plant population influences the use of solar radiation and nutrients for their growth and development. For the higher rice productivity, desired number of plant population per unit area is an important one for getting maximum yield (Das *et al.,* 2016; Choudhary *et al.,* 2022).

Weeds are the major biotic constraint to reduce the rice productivity worldwide (Das *et al.* 2016; Choudhary *et al.,* 2022). In transplanted rice, about 60% of the weeds emerge in the period between 1 week to 1 month after

Based on a part of M.Sc. Thesis of the first author submitted to Shaheed Gundadhur College of Agriculture and Research Station of the Indira Gandhi Krishi Vishwavidhyalaya, Jagdalpur, Chhatishgarh in 2019 (unpublished)

Corresponding author's Email: hpurnima29@gmail.com
[1]Guest Teacher, Krantikari Debaridhur College of Horticulture and Research Station Jagdalpur, Bastar, Mahatma Ghandhi University of Horticulture and Forestry, Durg Chhatishgarh 494001; [2]Principal Scientist, Shaheed Gundadhur College of Agriculture and Research Station, Indira Gandhi Krishi Vishwavidhyalaya, Jagdalpur, Chhatishgarh 494 001

transplanting. These emerging weeds are competing with rice at effective tillering stage and decline the quantity of panicles leading in reduction of grain yield. Weed management can be achieved by either application of pre-emergence or post - emergence or combination of both or manual weeding. The herbicides offer the most effective, economical and practical way of weed management (Sureshkumar and Durairaj, 2016).

A field experiment was conducted at the Shaheed Gundadhur College of Agriculture and Research Station, of the Indira Gandhi Krishi Vishwavidhyalaya, Jagdalpur, Chhattisgarh during rainy season (*kharif*) of 2019. The experiment was laid out in a split split plot design with 3 replications. The main plot treatment consisted of 2 scented rice varieties, viz. 'Dubraj Selection 1' (V_1) and 'Tarunbhog Selection 1' (V_2), sub plot treatments comprised 2 planting geometry, viz. 20 cm × 15 cm (G_1) and 20 cm × 20 cm (G_2), and sub- subplot consisted of 4 weed management practices, viz. pyrazosulfuron ethyl 10% WP @ 20 g/ha at 3 days after transplanting (DAT) + 1 Hand wedding (HW) at 25 DAT (W_1), bispyribac sodium 10% SC @ 20 ml/ha at 25 DAT + 1 HW at 50 DAT (W_2), 2 HW at 25 and 50 DAT (W_3) and absolute control (W_4). Soil of the experimental site was clay loam, (*Alfisol*) slightly acidic and medium in organic matter and available NPK. During *kharif* 2019, the normal average annual rainfall of the area was, 1,440 mm during cropping season but its distribution was very erratic. Major amount of precipitation occurs between June and September, a total of 1,740.20 mm rainfall was received with 78 rainy days. The maximum temperature varied from 31.7°C in 4th week of June to 30.7°C in 4th week of November, whereas the minimum varied from 13.8°C in 1st week of November to 13.1°C in 2nd week of December.

The major weeds found in association with transplanted rice during *kharif* 2019 were: *Ludwigia peploides* (Kunth) P.H. Raven, *Echinochloa colona* L., *Cyperus difformis* L., *Cyperus iria* L., *Commelina benghalensis* L. and, *Fimbristylis miliacea* (L.) Vahl.

Data pertaining to the total weed density on different weed species in Table 1. Rice field was infested with *Ludwigia peploides* and *Spilanthes acmella* (21%) *Cyperus iria* (14%), *Fimbristylis miliacea* (10%), *Commelina benghalesis, Cyperus difformis* (8%) in *Echinochloa colona.* (7%) and other weeds (11%).

Data relating to grain and straw yield are presented in Table 2. Grain yield of scented rice was not affected significantly not 2 varieties; however higher grain yield was observed in variety V_2 than the variety V_1. Planting geometry of G_1 resulted in higher grain yield than the G_2, because of greater weed suppression, which resulted in higher of crop dry matter, more effective tillers and less yield due to less dry matter accumulation, and less number of tillers/m². In case of different weed management practices, W_1 exhibited significantly higher grain yield, being at par with W_3 and W_2 treatments. Minimum crop-weed competition resulted in higher grain as also reported by Ghosh *et al.,* (2016).

Likewise, straw yield was significantly superior in W_2 treatment and it was at par with W_3 in among the weed management practices.

Table 1. Density of total weed density (m²), weed control efficiency (%) weed index of rice as influenced by different variety, planting geometry and weed management practices

Treatment	Total weed density/m² (number)				Weed-control efficiency (%)				Weed Index
	At 25 DAT	At 50 DAT	At 75 DAT	At harvesting	At 25 DAT	At 50 DAT	At 75 DAT	At harvesting	
Variety									
V_1	54.88 (7.06)	39.13 (5.26)	53.43 (6.01)	57.33 (6.33)	25.66	68.40	68.78	67.96	-0.82
V_2	41.25 (6.18)	35.51 (5.16)	45.60 (5.72)	49.18 (5.94)	29.29	66.02	67.50	67.46	3.25
SEm±	0.17	0.09	0.03	0.03	3.52	0.81	0.49	0.33	1.60
CD (P=0.05)	NS	NS	0.15	0.18	NS	NS	NS	NS	NS
Geometry									
G_1	37.18 (5.87)	33.54 (4.99)	45.28 (5.59)	50.03 (6.00)	30.21	66.58	68.33	67.41	-0.79
G_2	58.94 (7.37)	41.10 (5.43)	53.74 (6.13)	56.47 (6.27)	24.73	67.84	67.95	68.01	3.22
SEm±	0.05	0.03	0.07	0.03	1.32	0.30	0.20	0.24	3.00
CD (P=0.05)	0.20	0.11	0.27	0.11	5.17	1.51	NS	NS	NS
Weed-management									
W_1	10.97 (3.34)	7.77 (2.82)	23.86 (4.76)	26.25 (5.01)	82.80	93.05	85.23	84.66	-2.55
W_2	58.48 (7.58)	12.82 (3.57)	9.75 (3.12)	11.45 (3.38)	12.03	88.62	93.80	93.18	-6.94
W_3	56.55 (7.45)	14.39 (3.76)	10.23 (3.17)	11.81 (3.41)	15.06	87.17	93.52	93.00	0.00
W_4	66.26 (8.10)	114.31 (10.68)	154.21 (12.39)	163.51 (12.75)	0.00	0.00	0.00	0.00	14.35
SEm±	0.13	0.13	0.13	0.14	1.87	1.01	0.96	0.90	2.96
CD (P=0.05)	0.37	0.38	0.37	0.39	7.31	2.95	2.81	2.61	8.63

V_2, 'Tarunbhog Selection 1'; G_1, 20 × 15 cm; G_2 20 cm × 20 cm; W_1, Pyrazosulfuron ethyl 10% WP @ 20 g/ha at 3 DAT + 1 hand-weedings HW at 25 days after transplanting (DAT); W_2, bispyribac sodium 10% SC @ 20 ml/ha at 25 DAT + 1 HW at 50 DAT; W_3, 2 HW at 25 and 50 DAT and W_4, Absolute control

Table 2. Test weight, grain yield, straw yield, harvest index, cost of cultivation, net returns and benefit: cost ratio of rice as influence by different variety, planting geometry and weed-management practices

Treatment	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Cost of cultivation	Net returns (₹/ha)	Benefit: cost ratio
Variety							
V_1	18.28	4.12	5.44	4.30	129296	83599	1.82
V_2	14.43	4.40	5.67	4.35	137448	91750	2.01
SEm±	0.05	0.64	0.82	0.03			0.043
CD (P=0.05)	0.29	NS	NS	NS			NS
Geometry							
G_1	16.33	4.40	5.63	4.35	137335	91012	1.96
G_2	16.38	4.13	5.45	4.35	129409	84336	1.87
SEm±	0.14	0.61	0.75	0.31			0.040
CD (P=0.05)	NS	2.37	NS	NS			NS
Weed-management							
W_1	16.48	4.61	5.39	4.60	143638	98252	2.16
W_2	16.80	4.41	6.14	4.22	138594	91458	1.94
W_3	16.63	4.50	5.67	4.42	140874	92989	1.94
W_4	15.49	3.51	5.13	4.14	110383	67997	1.60
SEm±	0.16	0.71	1.06	0.29			0.048
CD (P=0.05)	0.48	2.92	2.53	0.85			0.14

V_1- 'Dubraj Selection 1', V_2- 'Tarunbhog Selection 1', G_1- 20 × 15 cm, G_2 - 20 cm × 20 cm, W_1- .Pyrazosulfuron ethyl 10% WP @ 20 g/ha at 3 DAT + 1 HW at 25 DAT, W_2- bispyribac sodium 10% SC @ 20 ml/ha at 25 DAT + 1 HW at 50 DAT, W_3- 2 HW at 25 and 50 DAT and W_4- Absolute control.

Harvest index was significantly superior in planting geometry of G_1 over the G_2. It might be the consequential effects of maximum tillers/hill and grains/panicle. In case of different weed management practices, treatment W_1 resulted in significantly higher harvest index. The herbicidal treatment had similar effect as that of hand-weeding in controlling weeds scented rice, which might be attributed to long term effective control of weeds during the growing period of crop as reported by Hasanuzzaman *et al.,* (2008).

Data presented in Table 3. Interaction effects of varieties × planting geometry × different weed management practices were found significant. The interaction of $V_1 \times G_1 \times W_1$ resulted in significantly higher grain yield than at par with $V_1 \times G_1 \times W_2$ and $V_1 \times G_1 \times W_3$. Interaction of $V_2 \times G_1 \times W_1$ resulted in significantly higher grain yield than at par with $V_2 \times G_1 \times W_3$, and $V_2 \times G_1 \times W_2$ showed statisti-

Table 3. Interaction effect on grain yield of rice as influence by different variety, planting geometry and weed management practices

Treatment	Grain yield (t/ha)				
	Variety				Mean
	V_1		V_2		
	Geometry				
	G_1	G_2	G_1	G_2	
Weed-management					
W_1	4.80	4.50	4.74	4.43	4.61
W_2	4.53	4.00	4.64	4.45	4.42
W_3	4.55	4.31	4.71	4.47	4.51
W_4	3.51	2.84	3.64	4.10	3.51
Mean V	4.13	4. 39			
Mean G	4.40	4. 13			
	V	G	W	G × W	V × G × W
SEm±	0.64	0.61	0.71	1.00	1.42
CD (P=0.05)	NS	2.37	2.07	NS	4.13

V_1, 'Dubraj Selection 1'; V_2, 'Tarunbhog Selection 1'; G_1, 20 × 15 cm; G_2, 20 cm × 20 cm; W_1, Pyrazosulfuron ethyl 10% WP @ 20 g/ha at 3 DAT + 1 hand-weedings HW at 25 days after transplanting (DAT); W_2, bispyribac sodium 10% SC @ 20 ml/ha at 25 DAT + 1 HW at 50 DAT; W_3, 2 HW at 25 and 50 DAT and W_4, Absolute control cally higher economic yield.

Different varieties and geometries showed higher gross and net returns, and benefit cost ratio, though not significantly in variety 'Tarunbhog selection 1' and planting geometry of 20 cm × 15 cm than the other treatments. Pyrazosulfuron ethyl 10% WP @ 200 g/ha at 3 DAT + 1 HW at 25 DAT also recorded significantly higher net returns, and benefit: cost ratio.

The variety 'Tarunbhog Selection 1' was found batter variety than 'Dubraj Selection 1' for grain yield. The planting geometry of 20 cm × 15 cm proved better in weed control and grain yield than the geometry 20 cm × 20 cm. Pyrazosulfuron ethyl 10% WP @ 200 g/ha at 3 DAT + 1 HW at 25 DAT also controlled all the weeds at initial stages and produced higher yield and yield attributing characters among all the weed management practices.

REFERENCES

Basha, J., Venkatesh, B. and Kumar, S. 2017. Rice (*Oryza sativa* L.) response to planting geometry and Method of Planting. *International Journal of New Technologies in Science and Engineering* **4**(1): 13–21.

Choudhary, A.K., Sood, P., Rahi, S., Yadav, D.S., Thakur, O.C., Siranta, K.R., Dass, A., Singh, Y.V., Kumar, A., Vijayakumar, S., Bhupenchandra, I., Dua, V.K., Shivadhar, Bana, R.S., Pooniya, V., Sepat, S., Kumar, S., Rajawat, M.V.S., Rajanna, G.A., Harish, M.N., Varatharajan, T., Kumar, A. and Tyagi, V. 2022. Rice productivity, Zn-biofortification and nutrient-use efficiency as influenced by Zn-fertilization under conventional transplanted-rice and the system of rice intensification. *Frontiers in Environmental Science* **10**: 869–994.

Dass, A., Shekhawat, K., Choudhary, A.K., Sepat, S., Rathore, S.S, Mahajan, G. and Chauhan, B.S. 2016. Weed management in rice using crop-competition–A review. *Crop Protection* **95**: 45–52.

Ghosh, D., Singh, U.P., Ray, K. and Das, A. 2016. Weed management through herbicide application in direct-seeded rice and yield modelling by artificial neural network. *Spanish Journal of Agricultural Research* **14**(2): 2,171–9,292.

Hasanuzzaman, M., Islam, Md, Obaidul. and Bapari, Md. S. 2008. Efficacy of different herbicides over manual weeding in controlling weeds in transplanted rice. *Australian Journal of Crop Science* **2**(1): 18–24.

MAFW, 2016. *Agricultural Statistics at a Glance 2016*. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi.

Sharma, D., Das, B.K., Kumar, V., Tiwari, A., Sahu, P.K., Singh, S. and Baghel, S. 2017. Identification of semi-dwarf and high yielding mutants in dubraj rice variety of Chhattisgarh through gamma ray based induced mutagenesis. *International Journal of Genetics* **9**(9): 298–303.

Sureshkumar R, and Durairaj, N.S. 2016. Weed characters and indices of transplanted-rice as influenced by different weed management practices. *International Journal of Agriculture Sciences* **8**(51): 2,221–2,223.

Indian Journal of Agronomy **68** (4): 434–438 (December 2023)

Research Communication

Effect of organic nutrient management on yield, quality, nutrient uptake and economics of aromatic rice (*Oryza sativa*) in Hill Zone of West Bengal

SANJIVANI KARKI[1], MRITYUNJAY GHOSH[2], BINOY CHETTRI[3], S. BANERJEE[4], T. BISWAS[5], P. BANDYOPADHYAY[6] AND S. GHOSH[7]

Uttar Banga Krishi Viswavidyalaya, Kalingpong, Nadia, West Bengal 734 316

Received: February 2023; Revised accepted: October 2023

ABSTRACT

A field experiment was conducted during the rainy (*kharif)* season of 2021 at the Uttar Banga Krishi Viswavidyalaya, Kalimpong, West Bengal, to study the response of 2 aromatic rice cultivars ('Kalture' and 'Kalonunia') under 4 organic nutrient management (cowdung manure @ 5 t/ha, vermicompost @ 1.5 t/ha, mustard-cake @ 0.5 t/ha, and leaf mould @ 1 t/ha). 'Kalonunia' exhibited greater tiller production (435/m^2), leaf-area index (3.08) and dry-matter accumulation (452 g/m^2) at 63 days after planting (DAT), and 'Kalture' showed taller plants (137.1 cm) and lodging susceptibility (score 4.0) at maturity. 'Kalonunia' performed significantly better in terms of grain yield (3.32 t/ha), non-lodging habit, protein content (7.25%) and net income (₹57,043/ha) than 'Kalture' cultivar. Although the application of vermicompost @ 1.5 t/ha resulted in the maximum grain yield (3.22 t/ha) and nutrient uptake (44.6 kg N, 16.4 kg P and 39.0 kg K/ha), mustard-cake @ 0.5 t/ha could be an alternative option owing to near-maximum grain yield (3.11 t/ha) with high protein content (7.1%), medium aroma (score 1.7), maximum net income (₹51,040/ha) and benefit: cost ratio (2.01) in Hill Zone of West Bengal.

Key words: Aromatic rice, Cultivar, Growth, Organic nutrient management, Quality, Yield

The Sikkim-Darjeeling Himalayas having extreme climatic and edaphic conditions represents one of the unique reservoirs of rice (*Oryza sativa* L.) genetic resources in the country. Among diverse rice landraces in the region, 'Kalture', having medium-slender aromatic grain, is cultivated by the farmers in the hills of Kalimpong and Darjeeling districts of West Bengal for a long time (Mondal *et al*., 2021). Another popular scented 'Kalonunia', also reported as *Kala nenia* or *Kala nina* or *Kala nooniah*, is traditionally cultivated in foothills (*tarai*) and plains of hill zone of North Bengal for hundreds of years (Ghosh *et al*., 2021). The word 'Kalonunia' had two parts: '*Kalo*' meaning black in Bengali represented black-husked grain, and '*nuni*a' indicated local rice group of the region. The earliest record of 'Kalonunia' rice could be found as *aman* paddy under *nenia* group in Darjeeling District (Hunter, 1876), and during that time it was known to the Europeans as a table rice by its export from the region. It was considered as the 'Prince of Rice' being highly regarded by the *Maharaj* of Cooch Behar because of its use for preparation of traditional dishes of winter celebrations like *payesh* (sweet rice), *bhog* (pulse intermixed rice), *polao*, *pitha* (home-made cake), *selroti* (ring-shaped sweet bread) etc. in the region.

In Himalayan hilly region of West Bengal, farmers grow rice landraces following traditional practices with either little or no nutrient-management practices. Therefore, a suitable approach of nutrient management is required to keep up the production of aromatic rice with desired quality and maintenance of soil health. Cowdung manure is commonly used in rice cultivation since ancient times in the state, while vermicompost is gaining importance in crop production in recent times and mustard-cake has been using by a small-group of farmers in short-grained aromatic rice cultivation in South Bengal (Ghosh, 2019). On the other hand, leaf mould, the locally-available decomposed material of forest leaves, is used as a nutrient input in garden and orchid cultivation in hilly areas of West Bengal. However, there is no report on use of leaf mould in high-value rice cultivation in the foothills of Himalayas in West Bengal till date. In the context, it is also understood that the

Based on M.Sc. (Agric.) Thesis of the first author submitted to the BCKV, Nadia, West Bengal in 2022 (unpublished)

[1]**Corresponding author's Email:** sanjivanikarki1@gmail.com
[1]M.Sc. Student, [2,6]Professor, [4]Assistant Professor, Department of Agronomy; [5]Professor, [7]Research Scholar, Department of Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741 252; [3]Field Assistant, Uttar Banga Krishi Viswavidyalaya, Kalimpong, West Bengal 734 316

use of organic manures either conventional, locally-available and/or non-conventional untested ones may help in sustenance of productivity and quality of traditional scented rice in gravelly-loam soil. Besides, the demand for organic aromatic rice is increasing in recent times, which initiates the sporadic production of organic 'Basmati' in north India, organic 'Joha' in Assam and organic 'Gobindabhog' in southern part of West Bengal during last 2 decades. Hence, the present study was undertaken to find out the appropriate organic nutrient source(s) for better growth, yield, quality and economics of traditional aromatic rice cultivars during rainy (*kharif*) season in Hill Zone of West Bengal.

A field experiment was conducted at the Regional Research Station Farm (27°05'94" N, 88°46'95" E and 1,140 m altitude) of the Uttar Banga Krishi Viswavidyalaya (UBKV), Kalimpong, West Bengal, India during rainy (*kharif)* season of 2021. The soil of the field was classified as Lithic, Order Alfisol, gravely-loam in texture on steep slide slopes, grayish-brown, acidic (*p*H 5.1), high in organic carbon (8.5 g/kg) and available nitrogen (211.5 kg/ha), low in phosphorus (19.2 kg/ha) and potassium (112.9 kg/ha). The experiment was laid out in a split-plot design with 3 replications, which consisted of 2 traditional aromatic rice cultivars ('Kalture', and 'Kalonunia') in main plots and 4 organic nutrient-management practices (cowdung manure @ 5 t/ha, vermicompost @ 1.5 t/ha, mustard cake @ 0.5 t/ha and leaf mould @ 1 t/ha) in subplots. The nutrient content in different sources based on dry-weight basis was as follow: cowdung manure (0.5, 0.2 and 0.5%), vermicompost (1.3, 1.2 and 0.9%) mustard-cake (4.8, 1.0 and 1.0%) and leaf mould (2.2, 0.5 and 1.3%). 25 days old seedlings @ 2-3/hill were transplanted manually at a spacing of 20 cm × 15 cm. Two hand-weedings were done at 20 and 40 days after transplanting (DAT) in all the plots. The crop was raised with south–west monsoon rainfall (1730.8 mm), but it received scanty rainfall (2.3 cm) during post-flowering and grain-development stage in November.

The growth attributes of scented rice like plant height, tillering habit, dry-matter (DM) production at different stages were noted, while yield components and grain yield were determined at maturity. The rating of lodging of plants in each plot was done at hard dough stage following the scale mentioned in Standard Evaluation System for Rice (IRRI, 1996). The grain quality parameters like protein content (total N × 5.95), gelatinization temperature by alkali digestibility test (Little *et al.,* 1958) and aroma (Nagaraju *et al*., 1991) were determined at the Aromatic Rice Laboratory of BCKV, and the economics of cultivation was calculated as per local rates. The variability in cost of seed was recorded as ₹800/ha for 'Kalture' (20 kg/ha and ₹40 kg/ha) and ₹1,000/ha for 'Kalonunia' (20 kg/ha and ₹50/kg). On the other hand, the variable costs for organic manures were ₹15,900/ha for cowdung manure, ₹18,900/ha for vermicompost, ₹10,900/ha for mustard-cake, and ₹14,900/ha for leaf mould.

Benefit: cost ratio was calculated. The nutrient content (N, P and K) in grain and straw were determined in Chemical Analysis Laboratory. The data obtained in the study were analyzed using on-line OPSTAT software (*www.hau.ernet.in/opstat.html*) following standard statistical procedures.

The plant height, tillering pattern and dry-matter (DM) accumulation of both rice cultivars were gradually increased at varied rate toward maturity. 'Kalture' had taller plants (137.1 cm) at harvesting and lodging (Table 1) susceptibility (score 4.0) at hard dough stage, while 'Kalonunia' did not show lodging. The rice crop treated with cowdung manure @ 5 t/ha or vermicompost @ 1.5 t/ha became susceptible to lodging and most of the plants (>50 %) lodged slightly (score 3.0) at hard dough stage. But less lodging was noted in the plots receiving mustard-cake @ 0.5 t/ha (score 2.4) or leaf mould @ 1.0 t/ha (score 1.7). It could be assumed that cowdung manure and vermicompost might have less effect on the stiffness of stem developed at tillering phase of tall-indica rice.

'Kalture' had early tillering habit, but 'Kalonunia' produced greater number of tillers in unit area (434.8/m^2) at 63 DAT. The tillering pattern indicated that, both the cultivars produced >12 tillers/hill at the foothills of Himalayas in West Bengal. The LAI was significantly influenced at 63 DAT only, where 'Kalonunia' had more leaf area (3.08) than 'Kalture' (2.72). The use of cowdung manure @ 5 t/ha resulted in the maximum dry-matter yield (453.1 g/m^2) at 63 DAT owing to its slow release of nutrients to make available to the crop for a longer period even at later stage.

With regard to yield components, 'Kalture' produced < 10 panicles/hill, < 80 filled spikelets/panicle, straw-coloured grain with purple spot at tip and test weight of > 16 g; while 'Kalonunia' had < 11 panicles/hill, > 90 filled grains/panicle, black-coloured grain with medium-long black awn and 1,000-seed weight of < 13 g. 'Kalonunia' gave greater grain yield (3.32 t/ha) owing to significant improvement in number of panicles/m^2 (356.2) and filled grains/panicle (90.1) than 'Kalture' (2.86 t/ha). However, lower grain yield of 'Kalonunia' rice was reported as 2.98 t/ha (Sarkar *et al*., 2020) when grown in New Alluvial Zone of West Bengal. Both the scented rice cultivars, being tall-indica type, had straw yield of > 6.0 t/ha and harvest index of < 35.0%. The application of vermicompost @ 1.5 t/ha resulted in higher grain yield (3.22 t/ha), being at par with mustard-cake @ 0.5 t/ha (3.11 t/ha), while the lowest yield (2.88 t/ha) was obtained with cowdung

Table 1. Effect of organic manures and cultivars on growth and yield of traditional aromatic rice in hill zone of West Bengal

Treatment	Plant height (cm)	Tillers/m² at 63 DAT	LAI at 63 DAT	Dry-matter accumulationat 63 DAT (g/m²)	CGR (g/m²/day) at 42–63 DAT	Panicles/ m²	Filled grains/ panicle	1,000-grain weight (g)	Grain yield (t/ha)	Lodging (score)
Cultivar										
'Kalture'	137.1	402	2.72	421	12.5	325	77.4	16.09	2.86	4.0
'Kalonunia'	126.9	435	3.08	452	14.0	356	90.1	12.87	3.23	1.0
SEm±	0.82	4.0	0.05	1.2	0.23	2.3	0.8	0.05	0.01	0.07
CD (P=0.05)	5.04	24.4	0.32	7.1	1.44	14.4	4.7	0.29	0.06	0.43
Organic nutrient management										
Cow dung manure @ 5 t/ha	126.5	410	3.03	453	14.7	335	79.5	14.57	2.88	3.0
Vermicompost @ 1.5 t/ha	134.1	438	2.85	419	11.9	366	85.6	14.68	3.22	3.0
Mustard cake @ 0.5 t/ha	131.6	415	2.87	438	12.9	339	84.9	14.69	3.11	2.4
Leaf mould @ 1 t/ha	135.8	412	2.83	434	13.5	323	85.0	13.98	2.97	1.7
SEm±	1.71	5.6	0.06	2.4	0.32	7.6	1.17	0.32	0.07	0.23
CD (P=0.05)	5.26	17.3	NS	7.3	0.97	23.5	3.60	NS	0.21	0.69

DAT, Days after transplanting; CGR, crop-growth rate

Table 2. Effect of organic manures and cultivars on grain quality, nutrient uptake and economics of traditional aromatic rice of in hill zone of West Bengal

Treatment	Protein content (%)	Alkali spreading (score)	Aroma (score)	Nutrient uptake (kg/ha)			Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net income (₹/ha)	Benefit: cost ratio
				N	P	K				
Cultivar										
'Kalture'	6.72	5.7	1.6	43.1	15.6	38.1	52,301	89,378	37,077	1.71
'Kalonunia'	7.25	6.0	1.8	44.5	16.5	39.0	52,501	104,545	57,044	2.09
SEm±	0.04	0.18	0.15	0.05	0.05	0.06		264.3	264.5	0.01
CD (P=0.05)	0.23	NS	NS	0.34	0.28	0.34		1,630.6	1,632.0	0.04
Organic nutrient management										
Cowdung manure @ 5 t/ha	6.66	5.8	1.58	43.8	15.9	38.4	52,276	94,537	42,262	1.81
Vermicompost @ 1.5 t/ha	7.08	6.0	1.58	42.8	15.8	38.3	55,276	104,038	48,762	1.88
Mustard-cake @ 0.5 t/ha	7.14	6.3	1.72	44.6	16.4	39.0	50,776	101,816	51,040	2.01
Leaf mould @ 1 t/ha	7.06	5.3	1.88	44.0	16.0	38.7	51,276	97,454	46,178	1.90
SEm±	0.04	0.21	0.14	0.09	0.04	0.05		1,937.4	1,937.3	0.04
CD (P=0.05)	0.11	0.63	NS	0.26	0.12	0.16		5,968.4	5,968.4	0.11

Cost of cowdung manure (₹3/kg), vermicompost (₹12/kg), mustard-cake (₹27/kg); leaf mould (₹14/kg)
Price of grain: 'Kalture' (₹27/kg), 'Kalonunia' (₹30/kg); price of straw: 'Kalture' 'Kalonunia' (₹2/kg)

manure @ 5 t/ha. The maximum grain yield obtained owing to application of vermicompost @ 1.5 t/ha could be attributed to greater number of panicles/m^2 (366), number of filled grains/panicle (85.6) and 1,000- grain weight (14.68 g). Although the nutrient content in mustard-cake and leaf mould was higher than vermicompost, but the quantity applied for the latter one was much more to supply the similar dose of nutrients. Moreover, vermicompost, having bulky nature and rich source of macro- and micro-nutrients, vitamins, plant-growth regulators, beneficial microflora, might have better effect on improvement in growth and yield of traditional aromatic rice in hilly soil of West Bengal.

Although both aromatic rice cultivars had medium-slender (MS) white kernels, 'Kalonunia' had higher protein content (7.25%), alkali spreading value (score 6.0) and aroma (score 1.78) than 'Kalture' (6.72%, score 5.68 and score 1.6). The alkali score indicated that 'Kalture' had intermediate-low gelatinization temperature (GT), while 'Kalonunia' could be categorized into low GT (55–69^{o}C) category. However, Ghosh *et al*. (2021) recorded medium GT or ASV (score 3.9) of 'Kalonunia' rice in New Alluvial Zone of West Bengal. Among organic nutrient management practices, the use of mustard-cake resulted in the maximum protein content (7.14%) and moderate aroma (score 1.7). The protein content in grains obtained from mustard-cake-applied plots could be supported by the higher N content in grain as observed in N uptake values (Table 2). On the contrary, Prakash *et al*. (2002) reported higher protein content in Pusa Basmati 1 owing to application of FYM compared to commercial manures (processed city waste, vermicompost, and oil cake pellets and chemical fertilizers).

With regard to N, P and K uptake, 'Kalonunia' recorded the higher values for grain, straw and total uptake after harvesting compared to 'Kalture', except K uptake in straw in our study. Mean cultivar total N, P and K uptake was 43.8, 16.1 and 38.6 kg/ha, which were less than that reported for 'Kalonunia' rice in Coochbehar district of West Bengal by Heisnam *et al.* (2020). Among the 4 organic nutrient management practices, the application of mustard-cake @ 0.5 t/ha resulted in the highest total N (44.6 kg/ha) uptake (16.4 kg/ha) and K uptake (39.0 kg/ha) in the plants at maturity, but the maximum N and K uptake in straw and P uptake in grains were noted with the plants grown in vermicompost-applied plots.

The common expenditure incurred irrespective of cultivar and organic nutrient management was calculated as ₹36,376/ha, but variable cost included the cost of seeds and manures as per treatment schedule. Thus, total cost of cultivation varied between mustard cake applied plot (₹50,176/ha) and vermicompost-based nutrient-management (₹55,276/ha). But Paul *et al*. (2021) reported less cultivation cost for 'Kalonunia' rice under farmers' practice (₹35,580/ha) and integrated nutrient management (₹36,235–38,225/ha) in Jalpaiguri district within the native region of West Bengal. 'Kalonunia' recoded higher net income (₹57,044/ha) and benefit: cost ratio (2.09) owing to its greater yield and higher selling price than 'Kalture' (₹37,077/ha and 1.71). With regard to net income, 4 organic sources could be arranged as: mustard-cake (₹51,040/ha)> vermicompost (₹48,762/ha)> leaf mould (₹46,178/ha) > cowdung manure (₹42,261/ha). The application of mustard-cake @ 0.5 t/ha could result in B : C ratio of >2.0, but the other 3 organic nutrient management recorded B : C ratio <2.0 (1.81–1.90). However, Banerjee (2011) reported that the combined application of FYM and mustard-cake to a traditional rice (cv. 'Gobindabhog') resulted in the highest net return (₹19,190/ha) and higher B : C ratio (1.87) in New Alluvial Zone of West Bengal. In another study, Kumari *et al*. (2013) observed that scented rice ('Birsamati') receiving *dhaincha* (*Sesbania* sp.) green-manuring @ 5 t/ha and farmyard manure @ 10 t/ha was found to be most appropriate organic nutrient-management system for higher productivity as well as profitability.

It can be concluded that, 'Kalonunia' performed better in terms of grain yield, non-lodging habit, protein content and net income than 'Kalture' in our study. Among four organic nutrient management practices, mustard-cake @ 0.5 t/ha might be a good option owing to near-maximum yield with higher protein content moderate aroma, maximum net income and B : C ratio in Hill Zone of West Bengal.

REFERENCES

Banerjee, S. 2011. Development of organic production system for indigenous aromatic rice of West Bengal. Ph.D. Thesis, B.C.K.V., Mohanpur, Nadia, West Bengal, India. (unpublished)

Ghosh, M. 2019. Aromatic Rice of West Bengal: Diversity, Production and Marketing (in Bengali). Mehanati Prakashani, Hooghly, West Bengal.

Ghosh, M., Dolui, S., Das, B., Roy, K., Mary Pyngrope, D., Gorain, J., Paul, K., Karforma, J., Ghimiray, T.S. and Ghose, T.K. 2021. Morpho-agronomic and molecular characterization of black husked aromatic Kalonunia rice of Terai region of West Bengal. *Plant Physiology Reports*, http://doi.org/10.1007/54502.021-00633W.

Heisnam, P., Abhinash, M., Bidyapati, N., Irungbam, P., Loitongbam, B., Devi, K.L., Phurailatpam, A., Mitra, B. and Roy, A.S. 2020. Response of integrated nutrient management on nutrient uptake of aromatic rice and its residual effect on lentil yield cropping system under Terai Region of West Bengal. *International Journal of Current Microbiology and Applied Sciences* **11**: 1,502–1,510.

Hunter, W.W. 1876. *A Statistical Account of Bengal: Districts of Darjiling and Jalpaiguri, and State of Kuch Behar*, vol. 10, Trubner & Co., London, U.K.

IRRI. 1996. *Standard Evaluation System for Rice,* edn 4. Edition, International Rice Research Institute, Manila, Philippines.

Kumari, N., Singh, A.K., Pal, S.K. and Thakur, R. 2010. Effect of organic nutrient management on yield, nutrient uptake and nutrient balance sheet in scented rice (*Oryza sativa*). *Indian Journal of Agronomy* **55**(3): 220–223.

Little, R.R., Hidder, G.B. and Dawson, E.H. 1958. Differential effect of dilute alkali on 25 varieties of milled white rice. *Cereal Chemistry* **35**: 111–126.

Mondal, D., Kantamraju, P., Jha, S., Sundarrao, G.S., Bhowmik, A., Chakdar, H., Mandal, S., Sahana, N., Roy, B., Bhattacharya, P.M., Chowdhury, A.K. and Choudhury, A. 2021. Evaluation of indigenous aromatic rice cultivars from subHimalayan Terai region of India for nutritional attributes and blast resistance. *Scientific Reports* **11**: https://doi.org/10.1038/s41598-021-83921–7.

Nagaraju, M., Mohanty, K.K., Chaudhury, D. and Gangadharan, C. 1991. A simple screening technique to detect scent in rice. *Oryza* **28**: 109–110.

Paul K., Das B., Das K. and Das, M. K. 2021. Nutrient management in Bengal aromatic rice of Terai-Teesta Alluvial Zone in West Bengal. *Journal of Krishi Vigyan* **10**(1): 175–178.

Prakash, Y.S., Bhadoria, P.B.S. and Rakshit, A. 2002. Relative efficacy of organic manure in improving milling and cooking quality of rice. *International Rice Research Notes* **27**(1): 43–44.

Sarkar, S., Ghosh, M., Bera, P.S., Paul, K. and Saha, G. 2020. Effect of establishment methods on aromatic rice (*Oryza sativa*) genotypes in lower Gangetic plains of West Bengal. *Indian Journal of Agronomy* **65**(2): 171–174.

Indian Journal of Agronomy **68** (4): 439–442 (December 2023)

Research Communication

Influence of seed rate and foliar nitrogen on productivity and profitability of wheat (*Triticum aestivum*) in green manure basmati rice (*Oryza sativa*) wheat cropping system

SUDESHNA TIKAIT[1], K. S. SAINI[2], JAGMOHAN KAUR[3] AND PRABHJIT KAUR[4]

Punjab Agricultural University, Ludhiana 141 004

Received: December 2022; Revised accepted: October 2023

ABSTRACT

A field experiment was conducted during the winter (*rabi)* season of 2021–22 at Punjab Agricultural University, Ludhiana to study the effect of varied seed rate and 3% foliar nitrogen application at different stages on productivity and economics of wheat (*Triticum aestivum* L.) green manure basmati rice (*Oryza sativa* L.) (T) wheat cropping. The treatments consisted of T_1 recommended seed rate (100 kg/ha) with 3% foliar N application at 21 25 days after sowing (DAS), T_2 (45–50 DAS) and T_3 (60 65 DAS); T_4 (10% reduced seed rate (90 kg/ha) with 3% foliar N application at 21 25 DAS), T_5 (45 50 DAS) and T_6 (60–65 DAS); T_7 (20% reduced seed rate (80 kg/ha) with 3% foliar N application at 21 25 DAS), T_8 (45–50 DAS), T_9 (60–65 DAS) and T_{10} (control). The treatments were laid out in randomized block design with 3 replications. Significantly higher number of tillers (390.3 grains/pike (39.3), longer spike length (11.9 cm) were obtained from treatment T_9. Similarly, higher grain yield (5.41 t/ha), net returns (99,760/ha) and benefit cost ratio (2.33) were recorded with treatment (T_9). Thus 20% reduced seed rate (80 kg/ha) with 3% foliar nitrogen application at 60 65 DAS claimed better management practices in achieving higher yield, yield attributes and net returns.

***Key words*:** Economics, Foliar nitrogen, Green-manure, Seed rate, Wheat, Yield

Wheat (*Triticum aestivum* L.) is most important cereal crop cultivated widely around the world. After China, India leads in area and production of wheat by achieving 2nd position. It supports population by providing 40% of total food basket in country. In India, around 29.8 million hectares (m ha) land is under wheat cultivation, with production of 99.70 million tonnes. Rice (*Oryza stavia* L.) –wheat cropping system is a predominant cropping system around the world. It has been practiced over 13.5 m ha land under Indo-Gangetic region, out of which 10 m ha is in India. Due to intensive practices of rice wheat cropping system in this region, crop productivity has attained plateau sometimes it shows decreasing pattern and sustainability of this cropping system become questionable (Vijayakumar *et al.,* 2019). It compels scientist to feel for adopting different management practices like inclusion of green-manure crop in the system which helps in ameliorating problem related to sustainability as well as improving soil health (Saini *et al*., 2020). Now –a -days residue burning become a headache in north-western part of our country where farmers are forced to burn residue due to short window between harvesting of rice and sowing of wheat. Seed rate strongly determines yield by influencing competition among plant for various natural resources. So, optimum seed rate helps in attaining crop production and productivity by improving nutrient availability, light interception for photosynthesis, proper soil environment capable to take out nutrient and water. In order to maximize the use of natural resources without compromising the sustainability of the production system, plant population should be optimized for increased yield by reassessing seed rate. Nitrogen play crucial role for growth and development which must translocate photosynthates from vegetative to reproductive part that helps in enhancing grain yield. In this regard, foliar application of nitrogen can be a viable option by feeding directly to vegetative part as supplemental basis. Considering these points, present study was conducted to evaluate response of wheat in terms of productivity and profitability to varied seed rate and foliar nitrogen application in green manure basmati rice wheat cropping system.

Based on a part of M.Sc. Thesis of the first author, submitted to the Punjab Agricultural University, Ludhiana, Punjab in 2022 (unpublished)

[1]**Corresponding author's Email:** sudeshnatikait@gmail.com
[1]M.Sc. Student, [2]Principal Agronomist, [3]Senior Agronomist, [4]Research Fellow (Ph.D. Scholar), Department of Agronomy, Punjab Agricultural University, Ludhiana 141 004, Punjab

A field trial was carried out during 2021–22 starting from summer season with sowing of green manure crop up to the harvesting of wheat crop to assess the effect of seed rate with foliar nitrogen application at different stages on growth and yield of super seeder-sown wheat crop at Students' Research Farm, Punjab Agricultural University, Ludhiana. The experimental site is at 30.9° N and 75.8° E, 247 m above mean sea-level. The soil is loamy sand with 7.20 soil *p*H, 0.38% organic carbon, 208 kg/ha available nitrogen, 24.3 kg/ha available phosphorus and 199 kg/ha available potassium. Dhaincha as green manure crop was sown on 22 May; 2021 on some portion of field and another portion were kept free. Green-manure (38.77 t/ha) of green manure as fresh weight was incorporated on 5 July, 2021 before transplanting of basmati rice variety 'Punjab Basmati 7'on 15 July, 2021. Crop was maintained in submerged condition by keeping field in continuous flooding situation of 5-6 cm depth. Rice was harvested with the help of combine harvester. Data recorded at the time of basmati rice harvest was presented as:

During the winter season wheat variety 'PBW 752' was sown on 24 November 2021 with the help of super seeder in all plots to incorporate rice residue except control where the conventional sowing was followed. Ten different treatments were imposed on field during the winter season in plot size 6.5 m 3.3 m (21.45 m^2) in randomized block design with 3 replications. Treatments were selected as recommended seed rate (100 kg/ha) with 3% foliar N application at 21 25 days after sowing (DAS) (T_1), recommended seed rate (100 kg/ha) with 3% foliar N application at 45 50 DAS (T_2), recommended seed rate (100 kg/ha) with 3% foliar N application at 60 65 DAS (T_3),10% reduced seed rate (90 kg/ha) with 3% foliar N application at 21 25 DAS (T_4),10% reduced seed rate (90 kg/ha) with 3% foliar N application at 45 50 DAS (T_5),10% reduced seed rate (90 kg/ha) with 3% foliar N application at 60 65 DAS (T_6), 20% reduced seed rate (80 kg/ha) with 3% foliar N application at 21 25 DAS (T_7), 20% reduced seed rate (80 kg/ha) with 3% foliar N application at 45 50 DAS (T_8), 20% reduced seed rate (80 kg/ha) with 3% foliar N application at 60 65 DAS (T_9), the control (T_{10}). Residual effect of green manuring was studied on succeeding wheat crop. All the management practices were followed as per package of practices and crops were fed with recommended dose of fertilizers. Irrigation was applied according to crop requirement, considering climatic condition. Field kept in weed-free situation by hand-weeding and insect-pests free by adopting various plant-protection measures. Urea as nitrogen source was applied for foliar spray at the crown-root initiation, maximum tillering stage and jointing stage as per treatments. Standard procedures were maintained during taking field data on yield attributes and yield. Economics was calculated by including market prices of input as well as output and benefit cost ratio was calculated. Data recorded during field study were compiled and analysed with the help of analysis of variance (ANOVA) technique.

Varied seed rate and 3% foliar N application had significant influence on yield attributes of wheat (Table 2). Significantly longer spike length (11.9 cm), more number of effective tillers (390.3), more grains/spike (39.3) were recorded from treatment T_9, i.e. 20% reduced seed rate with 3% foliar N application at 60 65 days after sowing (DAS), being statistically at par with 20% reduced seed rate and 3% foliar nitrogen application at either 45 50 DAS or 21 25 DAS and 10% reduced seed rate with 3% foliar nitrogen application at either 60 65 DAS or 45 50 DAS or 21-25 DAS (Table 2) whereas the control treatment i.e. 100 kg seed rate without foliar N application resulted in lower spike length (8.9 cm), number of effective tillers (358.3), grains/spike (33.2). Less competition for natural resources like congenial soil environment helps in improving nutrient availability, enhanced light interception for photosynthesis leading to translocate photosynthates to the assimilates of grains, resulted in more number of yield attributes. Our results confirmed the findings of Tigabu and Asfaw (2016) who recorded more number of tillers/plant and productive tillers/plant by using lower seed rate (75 kg/ha). Side-by-side foliar N application at different stages resulted in more assimilation of photosynthates compared to without foliar application. Our findings confirm the results of Ransing and Tomar (2019). However, 1000-grain weight was not significantly influenced by seed rate and foliar N application.

Data pertaining to yield parameters like grain yield, straw yield of wheat reflected significant influence of varied seed rate with 3% foliar N application (Table 2). Significantly higher grain yield, straw yield and biological yield were obtained from T_9 treatment whereas lower grain yield was recorded from the control treatment. It was observed that 10 20% reduced seed rate with 3% foliar

Table 1. Effect of green–manure crop on yield and yield attributing characters of Basmati rice (*Oryza sativa* L.)

Treatment	Plant height (cm)	Effective tillers/m^2 (No)	Panicle length (cm)	Grain yield (q/ha)	Straw yield (q/ha)
With green manure	114.13	530	26.1	45.3	73.4
Without green manure	112.6	456	22.1	43.1	71.8

Table 2. Effect of reduced seed rate and 3% foliar nitrogen application at different days after sowing (DAS) on yield attributes of wheat crop under green manure basmati rice wheat cropping system

Treatment	Effective tillers/m²	Grains/ spike	Spike length (cm)	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
T_1 (Recommended seed rate and 3% foliar N application at 21 25 DAS)	361.3	34.5	9.2	38.6	4.79	7.09	11.88	40.3
T_2 (Recommended seed rate and 3% foliar N application at 45 50 DAS)	363.2	34.9	9.4	38.7	4.81	7.11	11.92	40.4
T_3 (Recommended. seed rate and 3% foliar N application at 60 65 DAS)	364.5	35.1	9.5	39.0	4.83	7.12	11.95	40.4
T_4 (Reduced 10% seed rate and 3% foliar N application at 21 25 DAS)	380.0	36.4	10.6	39.3	5.12	7.53	12.65	40.5
T_5 (Reduced 10% seed rate and 3% foliar N application at 45 50 DAS)	386.4	38.8	11.4	39.7	5.32	7.81	13.13	40.5
T_6 (Reduced 10% seed rate and 3% foliar N application at 60 65 DAS)	388.7	39.1	11.8	40.0	5.38	7.86	13.24	40.7
T_7 (Reduced 20% seed rate and 3% foliar N application at 21 25 DAS)	385.1	38.5	11.1	39.5	5.29	7.77	13.06	40.5
T_8 (Reduced 20% seed rate and 3% foliar N application at 45 50 DAS)	387.2	39.0	11.6	39.9	5.36	7.84	13.20	40.6
T_9 (Reduced 20% seed rate and 3% foliar N application at 60 65 DAS)	390.3	39.3	11.9	40.1	5.41	7.89	13.30	40.7
T_{10} (Control)	358.3	33.2	8.9	38.4	4.54	6.73	11.27	40.3
CD (P=0.05)	19.51	3.14	1.40	NS	0.440	0.622	1.081	NS

nitrogen application at different days of sowing resulted in 12.8–19.2% and 11.9–17.2% more grain and straw yield respectively over the control treatment. This might be attributed to more number of yield attributing characters like number of tillers, spike length, grains/spike. Aulakh *et al*., (2018) and Matsuyama and Ookawa (2020) also pointed out that higher grain yield was achieved from using lower seed rate rather than higher seed rate. In addition, the higher grain yield in super seeder-sown treatments was recorded owing to better growth, development and partitioning of biomass in different phasic changes, longer time duration of greenness in crop, which resulted higher light interception and cop up with adverse effects of abiotic factors and synchronising in maturity of the crop (Islam *et al*., 2017). This leads to production of better and longer reproductive phases and transfer of assimilates to the ear. Thus, delayed maturity of crop in these treatments, awns contributed a lot than the crop sown with recommended seed rate with recommended N and 3% foliar N application treatments. Harvest index was found to be non-significant.

Economics of wheat (Table 4) indicated that treatment T_{10} i.e. control plot recorded higher cost of cultivation than

Table 3. Effect of reduced seed rate and 3% foliar nitrogen appli cation at different days after sowing (DAS) on economics of wheat crop under green-manure–basmati rice–wheat cropping system.

Treatments	Gross return (₹/ha)	Variable cost (₹/ha)	Net return (₹/ha)	Benefit: Cost
T_1(Recommended seed rate and 3% foliar N application at 21 25 DAS)	1,26,651	43,679	82,972	1.90
T_2 (Recommended seed rate and 3% foliar N application at 45 50 DAS)	1,27,139	43,679	83,460	1.91
T_3 (Recommended seed rate and 3% foliar N application at 60 65 DAS)	1,27,585	43,679	83,906	1.92
T_4 (Reduced 10% seed rate and 3% foliar N application at 21 25 DAS)	1,35,171	43,169	92,002	2.13
T_5 (Reduced 10% seed rate and 3% foliar N application at 45 50 DAS)	1,40,391	43,169	97,222	2.25
T_6 (Reduced 10% seed rate and 3% foliar N application at 60 65 DAS)	1,41,005	43,169	97,836	2.27
T_7 (Reduced 20% seed rate and 3% foliar N application at 21 25 DAS)	1,39,616	42,784	96,832	2.26
T_8 (Reduced 20% seed rate and 3% foliar N application at 45 50 DAS)	1,41,324	42,784	98,540	2.30
T_9 (Reduced 20% seed rate and 3% foliar N application at 60 65 DAS)	1,42,544	42,784	99,760	2.33
T_{10} (Control)	1,20,084	47,805	72,279	1.51

the other treatment, whereas less cost of cultivation was observed from treatments where 20% reduced seed rate and 3% foliar nitrogen application were used. The reason behind higher cost of cultivation was conventional sowing and higher seed rate which leads to higher variable cost. Higher gross, net returns and benefit: cost were recorded in 20% reduced seed rate and 3% foliar nitrogen application. This was owing to higher grain and straw yield.

Based on the study, it was concluded that 10–20% reduced seed rate with 3% foliar nitrogen application at different days of sowing resulted in 12.8 to 19.2% and 11.9 to 17.2% more grain and straw yield, respectively, over the control treatment. Higher economic benefit and lower cost of cultivation were obtained from reduced seed rate with 3% foliar nitrogen application.

REFERENCES

Aulakh, C.S., Singh, Hargopal., Walia, S.S., Phutela, R.P. and Singh, G. 2018. Evaluation of nutrient sources for organic production of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system in north-west India. *Indian Journal of Agronomy* **63**(2): 137–144.

Islam, M.S., Akter, H., Miah, M.J. and Farazi, M. 2017. Effect of foliar and soil application of nitrogen on the growth and yield of wheat. *Progressive Agriculture* **28**(4): 287–294.

Matsuyama, H. and Ookawa, T. 2020. The effects of seeding rate on yield, lodging resistance and culm strength in wheat. *Plant Production Science* **23**(3): 322–332.

Ransing, D.M. and Tomar, G.S. 2019. Production potential, economics and energetic as influenced by integrated nutrient management in soybean wheat cropping system. *Indian Journal of Agronomy* **64**(3): 298–303.

Saini, K.S., Kaur, Jagmohan, Singh, Thakar, Chahal, T.S. and Manhas, S.S. 2020. Productivity, economics and energetics of potato (Solanum tuberosum)-based systems as an alternative to rice (Oryza sativa) – wheat (*Triticum aestivum*) in Doaba region of Punjab. *Indian Journal of Agronomy* **65**(1): 125–129.

Tigabu, R. and Asfaw, F. 2016. Effects of seed rate and row spacing on yield and yield components of bread wheat (*Triticum aestivum* L.) in Dalbo Awtaru Woreda, Wolaita zone, southern Ethiopia. *Journal of Biology, Agriculture and Healthcare* **6**(7): 58–62.

Vijayakumar, S., Kumar, D., Shivay, Y.S., Anand, A., Sharma, D.K., Sharma, V.K. and Govindasamy, V. 2019. Growth and productivity of wheat (*Triticum aestivum*) as influenced by potassium application. *Indian Journal of Agronomy* **64**(3): 341–347.

Indian Journal of Agronomy **68** (4): 443–446 (December 2023)

Research Communication

Efficacy of pyroxasulfone and its combinations against weeds in wheat (*Triticum aestivum*)

LAKHAN BHALSE[1], A.K. JHA[2], BADAL VERMA[3], SHIVANGI RAGHUWANSHI[4], MUSKAN PORWAL[5] AND M.P. SAHU[6]

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482 004

Received: September 2022; Revised accepted: November 2023

ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2021–22 at the research farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh to study the efficacy of pre-emergence herbicides against weeds in wheat (*Triticum aestivum* L.). The experiment was laid out in a randomized block design with 3 replications and 8 weed control treatments. Major weed flora in the experimental site, viz. *Medicago polymorpha* (L.) (28.97%) and *Cichorium intybus* (L.) (26.19%) were predominant in dicot weeds and in monocot weeds, *Phalaris minor* (17.82%) was dominant. The weedy check plot had the higher density and dry weight of weeds. Hand weeding (once) was done at 25 DAS (day after sowing) in wheat, reducing weeds density and dry weight to the maximum extent at 40 DAS with a weed control efficiency (WCE) of 92.8%, proving superiority over other treatments. Among the herbicidal applications, pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha significantly reduced the monocot and dicot weeds density and dry weight, followed by pendimethalin + pyroxasulfone at 1250 + 127.5 g *a.i.*/ha. Pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha resulted in maximum values of growth parameters, viz. plant height (66.38 cm), number of tillers/m^2 (403.14) and yield attributing characters, viz. grains per earhead (51.00) and grain yield (5.65 t/ha) as compared to other herbicidal treatments.

Key words: Hand weeding, Herbicidal applications, Pre-emergence herbicides, Pyroxasulfone + metribuzin, Weed flora, Wheat

Wheat (*Triticum aestivum* L.) is an essential *rabi* season crop that plays a vital role in India's economy. It has a critical share in food bin with 36% share in the complete food grains which are produced from India, ensuring food and nourishment security (Sangwan *et al*., 2019). Wheat is grown on 223.40 million hectares, yielding 778.6 million metric tonnes worldwide. It is cultivated on 31.62 million hectares in India, producing 3420 kg/ha with a total production of 109.2 million metric tonnes (USDA 2021). In Madhya Pradesh, wheat is grown on 10.02 million hectares with total production of 16.52 million metric tonnes and yielding 3298 kg/ha (Anonymous 2021). Many variables influence wheat production, but one of the most severe reasons for low irrigated wheat yield is the infestation of weeds (Raghav *et al.*, 2023; Tanisha *et al.,* 2022). Weeding by hand or with animal-drawn equipment is not only inefficient but also quite costly due to increased labour and fuel costs (Jha *et al.,* 2011; Tomar *et al.,* 2023). Many herbicides, like sulfoslfuron, metribuzin, metsulfuron are used to control weeds in wheat. However, they have not shown to be very successful in managing all types of weeds. So, evaluating alternate herbicides for effective weed control in wheat became essential. Henceforth, present study was carried out to evaluate the performance of pre-emergence herbicides against weeds in wheat.

A field experiment was conducted during winter (*rabi*) season of 2021–22 at the research farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. The experiment was laid out in a randomized block design (RBD) with 3 replications and 8 weed control treatments. Treatments applied during the field experimentation were pendimethalin at 1000 g *a.i.*/ha; pyroxasulfone at 127.5 g *a.i.*/ha; pendimethalin + pyroxasulfone at 1250 + 127.5 g *a.i.*/ha; metribuzin at 300 g *a.i.*/ha; pendimethalin + metribuzin at 1250 + 280 g *a.i.*/ha; pyroxasulfone +

Based on a part of M.Sc. Thesis of the first author submitted to Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh in 2022 (unpubplished)

[3]**Corresponding author's Email:** badalv82282@gmail.com
[1,4]M.Sc. Student, [2]Assistant Professor, [3,5]Ph.D. Scholar, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482 004; [6]Senior Research Fellow, ICAR-Directorate of Weed Research, Maharajpur, Jabalpur, Madhya Pradesh 482 004

metribuzin at 127.5 + 280 g *a.i*/ha as pre-emergence (3 DAS); hand weeding once at 25 DAS and weedy check. The research was carried out on clayey soil with a medium organic carbon content (0.61%), accessible nitrogen content (371 kg/ha), phosphorus content (17.1 kg/ha) and potassium content (296 kg/ha) and neutral in reaction (7.1 *p*H). A total 53.3 mm of winter rainfall was recorded during the crop growth period. The average weekly maximum temperature was 21 to 38.4°C, while the average weekly minimum temperature was 4.8 to 18.2°C. Certified seed of wheat variety 'JW 3382' with a high germination per cent was seeded at a rate of 100 kg/ha. Herbicides were sprayed with a Knapsack sprayer equipped with a flat fan nozzle. The significant differences between treatments were compared by critical difference at a 5% probability level.

Among all the weeds, dicot weeds were dominant over monocot weeds. The major weed flora observed in the experimental field in association with the wheat were *Medicago polymorpha* (L.) (28.97%), *Cichorium intybus* (L.) (26.19%), followed by *Chenopodium album* (L.) (16.10%) and *Anagallis arvensis* (L.) (10.92%) in dicot weeds. While, among monocot weeds, *Phalaris minor* (17.82%) was dominant.

The total weed density at 40 DAS varied significantly due to different weed-management practices in wheat. A weed-free check treatment showed the lowest density of monocot and dicot weeds, while the highest weeds density was recorded in the weedy check (Table 1). Among the weed-management practices, a significantly lower density of total weeds was observed in hand-weeding at 25 DAS (3.05/m^2). However, it was at par with pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha (4.12/m^2) followed by pendimethalin + pyroxasulfone at 1250 + 127.5 g *a.i.*/ha. Pre-emergence application of herbicides inhibited the growth of newly germinated weed seeds or seedlings. Thus, it significantly reduced the total weed population during the initial periods of crop growth (Meena *et al*., 2019; Rani *et al*., 2021).

The total weed dry weight at 40 DAS was recorded minimum in the weed-free check, while the highest total dry weight was in the weedy check (Table 1). Among the different weed management treatments, hand weeding treatment recorded the lower dry matter of all the weed species compared to weedy check at 40 DAS, which recorded the highest values in respect of these parameters. In herbicidal treatments, application of pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha significantly reduced the dry matter of all the weed species (4.46 g/m^2), being statistically at par with pendimethalin + pyroxasulfone at 1250+127.5 g *a.i.*/ha (5.05 g/m^2). This was mainly due to better control of weed growth from germination to harvesting, resulting in lower dry weight of weeds.

Different weed-management treatments exerted their remarkable effect on weed control efficiency (Table 1). The range of weed control efficiency (WCE) among different weed-management practices varied between 53.0 and 92.8% over the weedy check. The highest WCE at 40 DAS was recorded under hand weeding treatment (92.8%), followed by the application of pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha (86.9%) and pendimethalin + pyroxasulfone at 1250 + 127.5 g *a.i.*/ha. These outcomes are in line with the results of Punia *et al*., (2020) and Lakra *et al*., (2022).

Various growth parameters and yield attributes, viz. plant height, number of tillers/m^2 and grains/earhead plays a vital role in increasing the productivity of wheat crop,

Table 1. Effect of different weed control treatments on total weed density, dry weight and weed control efficiency in wheat

Treatment	Weed density (no./m^2) 40 DAS	Weed dry weight (g/m^2) 40 DAS	Weed-control efficiency (%) 40 DAS
Pendimethalin at 1000 g *a.i.*/ha	7.15 (50.73)	8.40 (70.06)	53.0
Pyroxasulfone at 127.5 g *a.i.*/ha	5.68 (31.79)	6.77 (45.42)	69.5
Pendimethalin + pyroxasulfone at 1250 + 127.5 g *a.i.*/ha	4.58 (20.48)	5.05 (25.07)	83.2
Metribuzin at 300 g *a.i.*/ha	6.73 (44.82)	7.93 (62.41)	58.1
Pendimethalin + metribuzin at 1250 + 280 g *a.i.*/ha	4.70 (21.58)	5.26 (27.24)	81.7
Pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha	4.12 (16.45)	4.46 (19.47)	86.9
Weedy check	10.84 (116.99)	12.23 (149.23)	0.0
Hand weeding (One)	3.05 (8.85)	3.34 (10.70)	92.8
SEm±	0.07	0.08	-
CD (P=0.05)	0.21	0.25	-

Square root (X+0.5)-transformed values; values in the parentheses are original values; DAS - days after sowing

Table 2. Effect of different weed-control treatments on growth parameters, yield attributes and yield of wheat

Treatment	Plant height (cm) (60 DAS)	Number of tillers/m^2 (60 DAS)	Number of grains/ earhead	Grain yield (t/ha)	B:C Ratio
Pendimethalin at 1000 g *a.i.*/ha	61.2	378.0	40.0	4.83	2.67
Pyroxasulfone at 127.5 g *a.i.*/ha	61.3	383.5	43.0	5.01	2.57
Pendimethalin + pyroxasulfone at 1250 + 127.5 g *a.i.*/ha	63.8	394.1	47.0	5.62	2.72
Metribuzin at 300 g *a.i.*/ha	59.1	374.1	39.0	4.58	2.58
Pendimethalin + metribuzin at 1250 + 280 g *a.i.*/ha	63.1	391.1	45.0	5.05	2.69
Pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha	66.3	403.1	51.0	5.65	2.80
Weedy check	52.8	352.1	33.0	2.80	1.74
Hand weeding (One)	69.9	412.9	55.0	5.72	2.64
SEm±	0.82	2.82	0.96	52.95	-
CD (P=0.05)	2.48	8.54	2.92	160.60	-

DAS - days after sowing

which were favourably influenced by the weed management treatments (Table 2). Significantly, a higher value of all said parameters were recorded under weed-free (hand weeding at 25 DAS), while a lower values were recorded in the weedy check treatment. Amongst different herbicidal treatments, pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha resulted in higher values of plant height (66.3 cm), number of tillers/m^2 (403.1) and grains/earhead (51.0) followed by pendimethalin + pyroxasulfone at 1250 + 127.5 g *a.i.*/ha.

The application of herbicidal treatments resulted in a marked increase in weed control efficiency and yield attributes, which had significantly higher grain yields over the weedy check (Table 2). Pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha exhibited higher grain yield (5.65 t/ha), followed by pendimethalin + pyroxasulfone at 1250 + 127.5 g *a.i.*/ha and both treatments were at par with each other. Reduced competition for moisture, space, light and nutrients between crop and weeds along with effective suppression of weeds by these pre-emergence herbicides has helped in obtaining higher yield (Kumar *et al*., 2017; Singh *et al*., 2019). However, weedy check gave the lowest wheat grain yield due to severe competition from all types of weeds.

The minimum benefit cost (B:C ratio) ratio was found in weedy check treatment where weeds were not suppressed (Table 2). In the plot where pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha was used, the B:C ratio was found highest (2.80), followed by pendimethalin + pyroxasulfone at 1,250 + 127.5 g *a.i.*/ha (2.72).

It can be concluded that pyroxasulfone + metribuzin at 127.5 + 280 g *a.i.*/ha is the most suitable and effective weed management practice for achieving higher grain yield by reducing the weed growth throughout the critical crop period in wheat crop with higher net monetary returns.

REFERENCES

Anonymous. 2021. Annual Report 2021–2022, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of Madhya Pradesh.

Jha, A.K., Kewat, M.L., Upadhyay, V.B. and Vishwakarma, S.K. 2011. Effect of tillage and sowing management on productivity, economics and energetics of rice- wheat cropping system for Kamore Plataue and *Satpura hill zone of Madhya Pradesh. Indian Journal of Agronomy* **56**(1): 35–50.

Kumar, R., Singh, R.S., Jaidev and Kumar, M. 2017. Effect of herbicides on weeds, grain yield and soil health in wheat. *Indian Journal of Weed Science* **49**(1): 88–89.

Lakra, K., Pyare, Ram, Singh, Puneet Kumar, Verma, Sunil Kumar, Singh, Rajiv Kumar, Upadhyay, Kumar, Pravin and Tyagi, Vishal. 2022. Effect of irrigation schedule and herbicides application on growth and productivity of wheat (*Triticum aestivum*) in semi-arid environment. *Indian Journal of Agronomy* **67**(2): 129–136.

Meena, V., Kaushik, M.K., Dotaniya, M.L., Meena, B.P. and Das, H. 2019. Bio-efficacy of readi-mix *Science* **51**(4): 344–351.

Raghav, P., Jha, A.K., Badal, V., Rahul, K. and Richa, S. 2023. Bio-efficacy of pinoxaden as post-emergence herbicide against weeds in wheat crop. *Pollution research* **42**(1): 115–117.

Punia, S.S. Soni, J., Singh, S.K. and Kamboj, P. 2020. Management of herbicide resistant *Phalaris mino*r in wheat. *Indian Journal of Weed Science* **52**(3): 237–240.

Sangwan, M., Hooda, V., Singh, J. and Duhan, A. 2019. Herbicidal weed management in dual purpose tall wheat. *Indian Journal of Agricultural Sciences* **89**: 141–144.

Rani, Sarita, Kumar, Suresh, Hooda, V.S. and Kumar, Satish. 2021. Bio-efficacy of metribuzin based herbicide mixtures on weeds and productivity of wheat. *Indian Journal of Agronomy* **66**(4): 407–412.

Singh, R.S., Kumar, R., Kumar, M. and Pandey, D. 2019. Effect of herbicides to control weeds in wheat. *Indian Journal of Weed Science* **51**(1): 75–77.

Tanisha, Nirala, Jha A.K., Badal Verma, Pushpendra Singh Yadav, Mahendra Anjna and Lakhan Bhalse. 2022. Bio efficacy of pinoxaden on weed flora and yield of wheat (*Triticum aestivum* L.). *Biological Forum–An International Journal* **14**(4): 558–561.

Tomar, D.S., Jha, A.K., Verma, B., Meshram, R.K., Porwal, M., Chouhan, M. and Rajpoot, A. 2023. Comparative efficacy of different herbicidal combinations on weed growth and yield attributes of wheat. *International Journal of Environment and Climate Change* **13**(8): 889–898.

USDA. 2021. World Agricultural Production, United States, Department of Agriculture, Foreign Agricultural Service, Circular Series. WAP 2–21. February 2021.

Indian Journal of Agronomy **68** (4): 447–450 (December 2023)

Research Communication

Prediction of post-harvest soil nutrient status through multiple linear regression for targeted yield of hybrid maize

NIDHI LUTHRA[1], AJAYA SRIVASTAVA[2], U.P. SHAHI[3], VIJAY KANT SINGH[4], PRADEEP DEY[5] AND ANAND SINGH[6]

Department of Soil Science, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145

Received: April 2022; Revised accepted: December 2023

ABSTRACT

A field experiment was conducted during 2017–18 at Crop Research Centre (CRC), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, to develop post-harvest soil test values (PHSTVs) and response type of fertilizers with the help of fertilizer prescription equations for achieving targeted yield of hybrid maize following STCR principle. In the present study, the response of hybrid maize to selected four levels of nitrogen (N), phosphorus (P), and potassium (K) and three levels of farm yard manure (FYM) at graded fertility levels was studied. Nutrient requirements (NR) of maize were recorded as 22, 5 and 27 kg/tonnes for N, P, and K, respectively. The contribution of NPK nutrients was observed; from fertilizer (%CF) at 58.2, 62.7, and 420.4%, from soil (%CS) at 33.1, 26.8, and 22.7%, from FYM (% C FYM) at 45.2, 14.4 and 39.4% and from fertilizer with FYM (% IPNM) as 62.4, 63.5 and 427.6%, respectively. Integration of N, P, and K fertilizers with FYM (10 t/ha) resulted in fertilizer savings of 31.2%, 18%, and 16% over NPK alone for a target yield of 4500 kg/ha on soil test values of 150, 35 and 200 kg/ha of $KMnO_4$-N, Olsen-P and NH_4OAc-K, respectively. The fertilizer response type for phosphorus was “+ - - “. The response of hybrid maize to NPK fertilizers was higher when integrated with FYM as compared to NPK alone. The prediction equations for PHSTVs help in predicting soil test values (STVs) which may save the cost of testing.

***Key words*:** Grain yield, Fertilizer response, STCR, Nutrient requirement

Maize (*Zea mays* L.), the third most important crop after rice and wheat spread over 9.47 million ha with the production of 28.6 million tonnes/year in India (Kumar *et al.,* 2023). Maize is a nutrient-exhaustive crop hence, for getting optimum economic yield external nutrient input application is very crucial (Ramkrushna *et al.,* 2022). Low soil fertility levels and nutrient mining by intensively grown nutrients exhaustive crops are the major threats to sustainable crop production. Efficient nutrient management requires balanced fertilizer use and sound management practices (Sivaranjan *et al.,* 2018). Applying fertilizers without considering the soil fertility status and nutrient requirement of the crops, affects the soil health and crop productivity adversely. It is an undeniable fact that 40-year-old fertilizer recommendations may not hold true in the present context as there has been a quantifiable decline in the nutrient status of the soil over the years. Farmers are using imbalanced chemical fertilizers to get higher yields but the decision on fertilizer use requires knowledge of the expected crop yield and crop response to applied nutrients. To overcome these issues, yield targets using the STCR approach can be achieved with an economically viable, environmentally sustainable system without degrading and polluting the soil, air, and water. STCR is based on the quantitative idea of the fertilizer requirement according to the yield and nutritional requirement of the crop, % contribution from the soil available nutrient, and that of the applied fertilizer (Ramamoorthy *et al.,* 1967). Keeping in view the above facts, the present investigation was carried out to study the response type of N, P, K, and PHSTVs for the next crop by using fertilizer prescription equations for hybrid maize.

The experiment was conducted at CRC, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (29º N, 79º 29' E, and 243.84 above mean

Based on a part of M.Sc. Thesis of the first author submitted to Department of Soil Science, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand in 2018 (unpublished)

3Corresponding author’s Email: upshahi@gmail.com

[1]M.Sc., [2]Professor, Department of Soil Science, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145; [3]Professor, Department of Soil Science, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh 250 110; [4]Assistant Professor, Department of Soil Science, Punjab Agricultural University, Ludhiana, Punjab 141004; [5]Project Coordinator, ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh 462 038; [6]Assistant Professor, Department of Soil Science, Acharya Narendra Deva University of Agriculture and Technology, Ayodhya, Uttar Pradesh 224 229

sea-level) during 2017–18 as outlined by Ramamoorthy *et al.,* (1967). The soil was sandy loam with weak fine to medium-fine granular structure. The initial pH, organic carbon (%), available N (kg/ha), available P (kg/ha) and available K (kg/ha) were 6.8, 0.6, 135.5, 12.8, and 170.3, respectively. The experiment was conducted in 2 steps, i.e. fertility gradient (Exp. I) and test crop experiment (Exp. II).

In experiment, I, wheat ('UP 2526') was grown into three rectangular strips (I, II, and III) of equal size (59 m × 7.5 m) by adopting standard agronomic practices. The graded fertilizer doses imposed in strips I, II, and III were ($N_0P_0K_0$ as 0:0:0), ($N_{½}P_{½}K_{½}$ as 100: 100: 100), and ($N_1P_1K_1$ as 200: 200: 200), respectively.

For Experiment II, the field was divided into 3 equal strips corresponding to those made in experiment I. The experiment was laid out in a fractional factorial design comprising 8 treatments (7 treated + 1 control) in each FYM block covering 24 treatments (21 treated and 3 control plots) in each strip, resulting in a total of 72 plots (63 treated and 9 control plots) of 3 m × 3 m size. Various treatment combinations of N, P, K, and FYM were selected as suggested by AICRP on STCR. Hybrid maize (var. P 3377) was tested with 4 levels of N (0, 60, 120, and 180 kg/ha), P_2O_5 (0, 30, 60 and 90 kg/ha), and K_2O (0, 20, 40 and 60 kg/ha). Half a dose of N, a full dose of P, K, and FYM were applied as basal, and the remaining N was in two splits at 30–45 DAS and just before tasseling was applied.

Soil samples (before sowing and after harvesting of the crop) were analyzed for pH, EC, Organic carbon, Available N, Olsen's P, and Available K. Plant samples were also analyzed for total N, P, and K content by following the procedures outlined by Jackson (1967). The uptake of nutrients was obtained as the product of their concentrations and yield. With the help of data on nutrient uptake, crop yield, soil test values and fertilizer nutrients applied, nutrient required in kg to produce a tonnes of hybrid maize grain yield (NR), % contribution of nutrients from soil (CS), % contribution of nutrients from fertilizers (CF), % contribution of nutrients from farm yard manure (CFYM) and % contribution of nutrients from fertilizer with FYM (IPNM) were calculated as described by Ramamoorthy *et al.,* (1967). These basic parameters were transformed into simple, workable fertilizer adjustment equations, and a ready reckoner was prepared to calculate a specific yield target based on soil test values as per the method described by Ramamoorthy *et al.,* (1967).

The pre-sowing soil test values, fertilizer doses grain yield, and/or the uptake of NPK by the crop were used as independent variables and the PHSTVs as dependent variable, were predicted by multiple regression equations (Ramamoorthy *et al.,* 1971), which were obtained by the statistical evaluation of the dependence of the post-harvest soil test values and the associated parameters (independent variables).

Yield and nutrient uptake by exhaust crop wheat

Yield and NPK uptake of exhaust crop wheat indicated that fertility gradient has been created successfully since it followed the same trend as of the applied fertilizer nutrients, *i.e.* strip III > strip II > strip I. Strip III recorded an increase of 241.8 and 15.1 % in grain yield over strip I and II, respectively. Straw yield in strip III recorded an increase of 279.7 and 19% over strips I and II, respectively. It may be due to the application of graded levels of N, P, and K in strips which influenced the grain yield nutrient availability and nutrient uptake by the crop. The results corroborate with the findings of Singh *et al.,* (2020) and Singh *et al.,* (2021).

Soil fertility, yield, and nutrient uptake by hybrid maize

The range and average values of soil available nutrients, grain yield, and nutrient uptake by hybrid maize are given in Table 1. Organic carbon (OC) was slightly higher in strip III as compared to strip II and strip I. Available soil nitrogen, phosphorus, and potassium followed the following trend; strip III > strip II > strip I due to the highest N, P, and K fertilizer application in strip III. The results were in concordance with the results of Singh *et al.,* (2020). The highest grain yield, N, P, and K uptake was recorded in strip III followed by strip II, and least in strip I. Increased uptake of nutrients following an application of NPK fertilizers and FYM was due to the addition of nutrients and proliferous root system developed under balanced nutrient application resulting in more absorption of water and nutrients and creating an adequate soil physical environment (Singh *et al*., 2014). The integrated use of organic and inorganic fertilizers has proved superior to applied alone concerning nutrient uptake (Sharma *et al*., 2016). Increment in potassium uptake was observed in almost all the integrated treatments over the chemical fertilization. This might be due to enhancement in K availability by shifting the equilibrium among the forms of K from relatively exchangeable K to soluble K forms in the soil and also by reducing leaching losses (Pradeep *et al.,* 2012).

Basic parameters

The data indicated that nutrient contribution from chemical fertilizer along with FYM was greater than soil and without FYM (Table 2). The application of FYM might have played an important role in enhancing the microbial population which leads to the higher availability of nutrients and thereby efficiency of added nutrients. The organic acids released during the decomposition of added FYM in the soil might played a role in solubilizing phosphorus (Sharma *et al.,* 2016).

Table 1. Soil fertility status after exhaust crop experiment and grain yield and total nutrient uptake by hybrid maize under different strips

Particulars	Strip I		Strip II		Strip III		Whole plot	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Organic carbon	0.15–1.17	0.51	0.16–0.86	0.54	0.23–1.44	0.61	0.16–1.17	0.56
Alkaline $KMnO_4$-N(kg/ ha)	50.2–125.5	93.5	87.9–138	109.8	87.8–175.6	124.4	50.2–175.6	109.2
Olsen's-P (kg/ha)	10.5–18.4	14.4	11.2–18.9	15.3	11.2–21.7	17.7	10.5–21.7	15.8
NH_4OAc-K(kg/ha)	96.3–165.8	135.9	127.7–163.5	148.0	127.7–198	165.3	96.3–198.2	149.7
				Maize				
Grain yield (t/ha)	0.78– 10.50	4.60	1.44–8.89	5.66	2.17–9.33	6.68	0.78–10.50	5.65
N Uptake (kg/ha)	13.6–188.4	95.7	31.4–211.5	121.7	46.5–191	148.9	13.6–211.5	113.0
P Uptake (kg/ha)	4.1–35.7	19.8	9.0–41.0	23.0	8.6-36.8	30.1	4.1–41.0	23.0
K Uptake (kg/ha)	12.2–258.2	129.7	24–232.6	156.0	38.6–262.0	209.9	12.2–262.0	149.5

Table 2. Nutrient requirement and contribution of nutrients from soil, fertilizers, and FYM

Parameter	N	P	K
Nutrient requirement (NR) (kg/t)	22	5	27
Contribution from soil (CS) (%)	33.1	26.8	22.7
Contribution from fertilizer (CF) (%)	58.2	62.7	420.4
Contribution from FYM (CFYM) (%)	45.2	14.4	39.4
Contribution from fertilizer and FYM (IPNM) (%)	62.4	63.5	427.6

Fertilizer adjustment equations

Fertilizer adjustment equations for calculating the nutrient requirement with and without FYM were developed with the help of basic data. Using these fertilizer equations, ready reckoners are prepared for NPK alone and NPK + FYM @10 kg/ ha for achieving 4500 kg/ha yield targets of hybrid maize (Table 3). Fertilizer application using the above equations would be more economical and environmentally friendly. Fertilizer adjustment equations for hybrid maize are:

NPK alone

FN = 3.6 T–0.56 SN

FP_2O_5 = 0.71 T–0.97 SP

FK_2O = 0.64 T–0.06 SK

NPK + FYM

FN = 3.36 T–0.53 SN–0.72 FYM

FP_2O_5=0.70 T–0.96 SP–0.52 FYM

FK_2O = 0.63 T–0.06 SK–0.11 FYM

Multiple regression study and fertilizer response type

Relationship between grain yield as the dependent variable and the soil test values (SN, SP, SK), fertilizer doses (FN, FP, FK), FYM doses (ON, OP, OK) as well as interactions between soil test values and fertilizer doses as independent variables were established through a multiple regression equation.

Yield = - 77.7752 + 0.1417 * SN + 1.1004 * SP + 0.2432 * SK + 0.0118 * FN + 1.9499 * FP + 0.1208 * FK + 0.0009 * FN2 - 0.0138 * FP2 - 0.0073 * FK2 + 0.0004 * FNSN - 0.0360 * FPSP + 0.0033 * FKSK - 4.0672 * ON + 4.2668 * OK, R^2= 0.7312**

Out of eight possible responses, only in (+ - -) type of response site-specific optimum fertilizer dose of nutrient can be derived by differentiation provided that the three coefficients are significant at least 5% level of significance (STCR manual, 1985). The fertilizer response type thus derived from the regression equation given below suggests that the site-specific optimum fertilizer dose can be derived for phosphorus, i.e. "+ - -". While potassium with response type "+ -+" showed the optimum fertilizer dose and the maximum yield increase with the increasing soil test value.

Table 3. Ready reckoner for soil test-based fertilizer recommendations of N, P, and K for 4,500 kg/ha for hybrid maize

Soil test value (kg/ha)			Fertilizer dose NPK alone (kg/ha)			Fertilizer dose NPK + FYM (kg/ha)			% reduction over fertilizer alone		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
70	10	60	123	64	31	96	57	27	22.1	11.6	11.8
80	12.5	80	117	62	30	90	55	26	22.8	12.0	12.3
90	15	100	112	60	29	85	52	25	23.7	12.5	12.7
100	17.5	120	106	57	27	80	50	24	24.6	13.0	13.3
110	20	140	100	55	26	75	47	22	25.6	13.5	13.9
120	25	160	94	50	25	69	43	21	26.7	14.7	14.5
125	30	180	92	45	23	67	38	20	27.4	16.2	15.2
150	35	200	77	40	22	53	33	19	31.2	18.0	16.0

R^2 value	Nutrient	Response type
0.7312	Nitrogen	+++
	Phosphorus	+--
	Potassium	+-+

Prediction equations for PHSTVs of available N, P, and K for maize

PHSTVs prediction equations were developed for available N, P, and K for availing STVs. The predicted soil test values can be utilized for recommending the fertilizer doses for succeeding crops and hence, eliminating the need for soil tests after each crop. This provides a way for prescribing the fertilizer recommendations for the whole cropping sequence based on initial soil test values. The prediction equations given below with the R^2 value between 0.27 and 0.61 ($p > 0.01$), suggest that these equations could be used with confidence for the prediction of available N, P, and K after maize to make the soil test-based fertilizer recommendations for any succeeding crop.

Based on yield

$PHN = -9.3972 + 0.6124 * SN + 0.3250 * FN - 0.0123 * Y^*$ $R^2 = 0.54^{**}$

$PHP = 7.4910 + 0.1871 * SP + 0.1629 * FP + 0.0468 * Y$ $R^2 = 0.48^{**}$

$PHK = 125.0024 + 0.1634 * SK + 0.3551 * FK + 0.0926 * Y$ $R^2 = 0.27^{**}$

Based on uptake

$PHN = -6.9759 + 0.5605 * SN + 0.2839 * FN + 0.0803 * UN$ $R^2 = 0.55^{**}$

$PHP = 7.3058 + 0.0387 * SP + 0.1388 * FP + 0.2479 * UP$ $R^2 = 0.61^{**}$

$PHK = 128.4252 + 0.1170 * SK + 0.1785 * FK + 0.0889 * UK$ $R^2 = 0.36^{**}$

** Regression is significant at the 0.01 level

* Regression is significant at the 0.05 level

Based on the present study, it may be concluded that investigation provides a strong relationship for the fertilizer recommendations based on the target yield concept which can effectively work for 4500 kg/ha targeted yield in hybrid maize grown on Mollisols of Uttarakhand. Besides this, target yield-based fertilizer recommendations not only provide balanced nutrition to crops but are also able to sustain crop productivity as well as soil health.

REFERENCES

Jackson, M.L. 1967. Soil chemical analysis. *Printice-hall of India Private Limited New Delhi.*

Kumar, A., Avasthe, R., Singh, R., Babu, S., Das, S.K., Ravisankar, N., Panwar, A.S., Qureshi, A.A., Laha, R., Mishra, V.K., Bhupenchandra, I., and Prasad, S.K. 2023. Productivity and profitability of maize (*Zea mays*) cultivars under organic management conditions in mid-hills of Sikkim. *Indian Journal of Agronomy* **68**(1): 26–29.

Pradeep, G., Channanaik, D., Rajanna, G.A., Sannathimmappa, H.G., Ramesha, Y.M. and Veersha. 2012. Economics and nutrient uptake of rice (*Oryza sativa)* as influenced by various levels of FYM and cattle urine application in Bhadra command area of Karnataka. *Crop Research* **43**(1/3): 10–14.

Ramamoorthy, B., Agarwal, R.K. and Singh, K.D. 1971. Soil fertility management under multiple cropping. *Indian Farming* **21**: 50–52.

Ramamoorthy, B., Narasimham, R.L. and Dinesh, R.S. 1967. Fertilizer application for specific yield targets of Sonora 64. *Indian Farming* **17**(5): 43–44.

Ramkrushna, G. I., Layek, J., Das, A., Verma, B.C., Das, S., Mohapatra, K.P., and Ngachan, S. V. 2022. Nutrient management in maize (*Zea mays*) under shifting cultivation for higher productivity and sustainability in North-East India. *Indian Journal of Agronomy* **67**(4): 386–391.

Sharma, V.K., Pandey, R.N., Kumar, S., Chobhe, K.A. and Chandra, S. 2016. Soil test crop response-based fertilizer recommendations under integrated nutrient management for higher productivity of pearl millet (*Pennisetum glaucum*) and wheat (*Triticum aestivum*) under long term experiment. *Indian Journal of Agricultural Sciences* **86**(8): 1,076–1,081.

Singh, A., Shahi, U.P., Dhyani, B.P., Kumar, A., Kumar, S., Vivek and Kumar, A. 2021. Response of bread wheat and nutrient removal with new micronutrient molecules fertilization. *Indian Journal of Agricultural Sciences* **91**(5): 708–712.

Singh, S.B. and Chauhan, S.K. 2014. Productivity and economics of pearl millet as influenced by integrated nutrient management. *Annals of Plant and Soil Research* **16**(4): 356–358.

Singh, V.K., Gautam, P., Singh, S., Pareek, N. and Singh, V.P. 2020. Evaluation of soil fertility gradient experiment on the basis of crop yield, nutrient uptake and soil fertility. *International Journal of Current Microbiology & Applied Science* **9**(2): 2,435–2,440.

Sivaranjan, C., Sellamuthu, K.M., Santhi, R. and Maragatham, S. 2018. Effect of graded levels of fertilizers with FYM on yield and NPK uptake by hybrid maize in Vertic ustropept. *International Journal of Current Microbiology and Applied Science* **7**(4): 3,494–3,498.

Indian Journal of Agronomy **68** (4): 451–454 (December 2023)

Research Communication

Effect of phosphorus levels and varieties on yield and yield attributes of mung bean (*Vigna radiata*) in climate condition of Badghis, Afghanistan

MOHIBULLAH SAMIM[1], SHAMSULHAQ SHAMS[2] AND KAPILA SHEKHAWAT[3]

Faculty of Agriculture, Badghis Institute of Higher Education, Badghis, Afghanistan 3351

Received: June 2022; Revised accepted: October 2023

ABSTRACT

A field experiment was conducted during the spring season of 2020 at research farm of Badghis Institute of Higher Education, Badghis, Afghanistan to evaluate the effect of phosphorus levels and varieties on yield and yield attributes of mung bean [*Vigna radiata* (L.) R. Wilczek]. The experiment was laid out in a randomized complete-block design with 3 replications. The experiment was comprised 2, viz. varieties 'Mai 08' and 'Nayab 98' of mung bean with 4 phosphorus levels, viz. control, 40, 60 and 80 kg P_2O_5/ha. The results revealed that, mung bean crop fertilized with 80 kg/ha P_2O_5 gave the maximum branches/plant (6.4), pods/plant (24.88), pod length (6.28), seeds/plant (243.3), 1,000-grain weight (32.74), grain yield (1230.43 kg/ha), and harvest index (39.42). Phosphorus @ 80 kg P_2O_5/ha was found more economical for getting higher grain yield of mung bean crop. The maximum and higher number of branches/plant, number of pods/plant, number of seeds/plant, 1,000-grain weight, grain yield kg/ha, and harvest index were recorded with 'Mai 08' variety.

Key words: Mung bean, Phosphorus, Yield, Yield components

Mung bean [*Vigna radiata* (L.) R. Wilczek] is a short-duration leguminous crop, and can be grown in various cropping patterns owing to its ability to adapt to the poor environmental stresses such as low soil fertility and drought (Bourgault *et al*., 2010). It is widely cultivated throughout the Asia, (Choudhary *et al*., 2015). Mung bean contains about 51% carbohydrate, 10% moisture, 4% minerals and 3% vitamins (Ali *et al*., 2010). It contains 27% protein and has good amount of essential amino acids comparable with that of soybean (*Glycine max* (L.) Merr.]. Afghanistan is an agriculture-based economy where wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), maize (*Zea mays* L.) and pulses are major field crops. Among these, pulses constitute the main source of plant-based protein for the ever-rising human population in the country. The pulses are also excellent source of protein nutrition for livestock. In developing countries like Afghanistan where protein energy malnutrition is a serious challenge due to cereal-based dietary pattern. Inclusion of pulses in staple diet could help in overcoming the crisis of malnourishment. Further, the protein obtained from pulses is comparatively cheaper than animal-based protein sources, i.e. meat, egg and fish, owing to the low market prices of pulses (Jahish, 2016). In Afghanistan, farmers sow pulse crops with only 1 ploughing and hardly use any fertilizers and irrigation due to their poor socio-economic status and lack of know-how. As a result, the crop yield is very low (Hamim, 2016). However, mung bean yield is very poor in Afghanistan due to non-availability of high-yielding varieties, poor nutrient management, especially phosphorus (P), broadcasting of seeds and being a rainfed crop due to poor irrigation infrastructure (Choudhary *et al*., 2015; Noorzai *et al*., 2017).

The yield and quality of mung bean can be improved by applying best agronomic practices and use of high-yielding cultivars. The cultivars of mung bean vary in yield potential and yield components. The application of phosphorus to mung bean has been stated to increase dry-matter at harvesting, number of pods plant/plant, seeds pod/plant, 1,000-grain weight, seed yield and total biomass (Mitra *et al*., 1999). Phosphorus has been reported to have a significant role in growth and development of the plant and also in nitrogen fixation. Mung bean, being a leguminous crop, requires high phosphorus, but the optimum dose under Afghanistan condition is yet to be standardized. Ayub *et al*. (1999) obtained significantly higher seed yield from recent mung bean cultivars. Two promising mung bean varieties 'NM-92' and 'NM-54' were tested by Ayub *et al*.,

Based on a part of M.Sc. Thesis of the first author submitted to the Badghis Institute of Higher Education in 2020 (unpublished)

[1]**Corresponding author's Email:** m.samim123@gmail.com
[1]M.Sc. Scholar, Department of Agronomy, Faculty of Agriculture, [2]Assistant Professor (Agronomy), Badghis Institute of Higher Education; [3]Senior Scientists, Division Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi 110 012

(1999) and they reported higher number of pod-bearing branches/plant, number of pods plant and number of seeds pod/plant which highlight the importance of adoption of high-yielding varieties and high P requirement. Yadav *et al.* and Singh (2011) also found significant differences in yields and yield components of different mung bean cultivars in response to phosphorus application. Keeping in view the importance of phosphorus levels and mung bean cultivars, the present investigation was carried out to know the effect of P levels and different variety on yield and yield components of mung bean.

A field experiment was conducted during the spring season, 2020 at the research farm of Badghis Institute of Higher Education under Badghis, Afghanistan to evaluate the effect of phosphorus levels and varieties on yield and yield attributes of mung bean. The experiment was laid out in a randomized complete-block design with 3 replications. The treatments, comprised 2 mung bean varieties 'Mai 08' and 'Nayab 98' with 4 phosphorus levels (control, 40, 60 and 80 kg P_2O_5/ha) with a basal dose of nitrogen @ 20 kg/ha. Diammonium phosphate and urea fertilizer were used as source of phosphorus and nitrogen, respectively. All phosphatic and nitrogenous fertilizer were applied before sowing. The soil of the experimental site was low in available nitrogen and phosphorus and medium in available potassium. The crop was sown at the seed rate of 25 kg/ha and hand weeding were done at 30, 45 days after sowing. The data on number of pods/plant, number of seeds/pod, pod length, 1,000-grain weight, grain yield, straw yield and harvest index were recorded and analyzed statistically using Fisher's analysis of variance technique.

The data regarding the effect of different phosphorus management and varieties on number of branches/plant, number of pods/plant, pods length, number of seeds/plant, 1000-grain weight (g), grain yield (kg/ha), straw yield (kg/ha) and harvest index are given in Table 1. The result showed that, branches/plant significantly varied with the varieties. The maximum branches/plant were recorded with 'Mai 08' mung bean (5.1) over 'Nayab 98' (4.981). Different levels of phosphorus resulted in significant difference for number of branches/plant. The maximum branches/plant (6.4) were obtained from mung bean when fertilized with 80 kg P_2O_5/ha. It was followed by treatment 60 kg P_2O_5 and 40 kg P_2O_5/ha with 5.4 and 4.1 branches/plant, respectively. Significantly least number of branches/plant was recorded in control plot. The effect of varieties on number of pods/plant was found significant. The maximum pods/plant were recorded with the 'Mai 08' variety (21.013) compared with 'Nayab 98' (20.13). A significant variation in pods/plant of mung bean was observed owing to phosphorus application. Among different phosphorus doses, the higher values of pods/plant (24.88) were recorded form treatment 80 kg P_2O_5/ha, followed by 60 kg P_2O_5 and 40 kg P_2O_5/ha. The higher number of pods/plant might have been recorded owing to more vigour and strength attained by the plants. This resulted in attaining sufficient absorption of nutrients and a higher test weight. It was observed that, pod length due to varieties showed a significant difference. The highest pod length was recorded with 'Mai 08' (5.79 cm) compared with 'Nayab 98' (5.51 cm). The pod length of mung bean was significantly affected by different levels of phosphorus. Among different levels of phosphorus, a significantly higher pod length (6.49 cm) was recorded from treatment 60 kg P_2O_5/ha followed by 80 kg P_2O_5/ha and 40 kg P_2O_5/ha. The pod length from treatment of 60 kg P_2O_5/ha treated mung bean was significantly higher than all treatments and the lowest pod length was recorded in the control plot.

The difference in number of seeds/plant was significant due to the varieties. The maximum number of seeds/plant recorded with the variety 'Mai 08' (201.4) over 'Nayab 98' (196.3). Seeds/plant were significantly affected

Table 1. Effect of phosphorus levels and varieties on branches/plant, pods/plant, pod length, seed/plant, 1,000-grain weight, grain yield, straw yield and harvest index (%) of mung bean

Treatments	Branches/plant	Pods/plant	Pod length (cm)	Seeds/plant	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (kg/ha)	Harvest index (%)
Phosphorus levels (P_2O_5/ha)								
0 kg	4.1	16.7	4.38	149.5	26.78	0.86	1,490	36.7
40 kg	4.3	18.8	5.47	175.5	28.86	0.95	1,677	36.3
60 kg	5.4	21.9	6.49	227.1	30.82	1.14	1,823	38.4
80 kg	6.4	24.9	6.28	243.3	32.74	1.23	1,891	39.4
SEm±	0.04	0.18	0.065	1.505	0.181	0.006	15.8	0.27
CD (P=0.05)	0.13	0.56	0.198	4.565	0.552	0.019	48.1	0.82
Varieties								
'Nayab 98'	4.98	20.1	5.51	196.3	29.54	1.03	1,759	36.8
'Mai 08'	5.15	21.0	5.79	201.4	30.06	1.07	1,682	38.7
SEm±	0.03	0.13	0.463	1.064	0.128	0.004	11.2	0.19
CD (P=0.05)	0.09	0.394	0.140	3.228	0.390	0.013	34.0	0.58

by different levels of phosphorus. A significantly higher number of seeds/plant was recorded with 80 kg P_2O_5/ha (243.3), followed by 60 and 40 kg P_2O_5/ha which also significantly differed from each other producing 227 and 175 seeds/plant, respectively. The data pertaining to 1,000-grain weight showed significant difference between varieties. The higher 1,000-grain weight was recorded with 'Mai 08' (30.1 g) than 'Nayab 98' (29.5 g) variety. Among different levels of phosphorus, significantly higher 1,000-grian weight (32.7 g) was recorded from treatment 80 kg P_2O_5/ ha, followed by the treatment 60 kg P_2O_5/ ha and 40 kg P_2O_5/ha and all these treatments showed markedly higher values than the control. The result showed that, the grain yield between varieties varied significantly. The maximum grain yield was recorded with the variety 'Mai 08' (1,065 kg/ha) over variety 'Nayab 98' (1,028 kg/ha). A significantly higher grain yield (1,230.4 kg/ha) was recorded from treatment 80 kg P_2O_5/ha, followed by the application of 60 kg P_2O_5/ha and 40 kg P_2O_5/ha. All phosphorus fertilizer treatments resulted in significantly higher grain yield than the control. It was observed that, the straw yield showed significant difference due to varieties. The highest straw yield was recorded with 'Nayab 98' variety (1758.8 kg/ha) over 'Mai 08' (1,681.8 kg/ha). Different levels of phosphorus application showed significant difference on straw yield of mung bean. The maximum straw yield was recorded with treatment 80 kg P_2O_5/ha (1,891 kg/ha). Treatment with 80 kg P_2O_5/ha was found significantly superior to all treatments. The response to applied phosphorus was also obtained due to low availability in the soil (10.72 kg P_2O_5/ha). The data regarding harvest index between varieties showed a significant difference. The maximum harvest index was recorded with 'Mai 08' variety (38.66%) over 'Nayab 98' (36.78%). The varying levels of phosphorus applications indicates a significant effect on harvest index. A higher harvest index (39.42%) was noted with treatment 80 kg P_2O_5/ha, followed by treatment 60 kg P_2O_5/ha and 40 P_2O_5/ha. Kumar *et al.* (2012) also reported that, the increasing rate of phosphorus application significantly increased harvest index over the control plots.

Yadav *et al.* (2011) also found that the highest number of branches/plant in mung bean were recorded with the high dose of phosphorus application under P-deficit areas (Tesfaye *et al.,* 2007). Singh *et al.* (2007) also reported that varieties had a significant effect on number of pods/plant of mung bean. Muhammad *et al.* (2004) and Prasad *et al.* (2005) found that the number of pods/plant increased with the phosphorus application. It is evident from the results of Nadeem *et al*. (2003) that, pod length increases with increase in the phosphorus levels. The difference in number of grains/plant among the varieties might be due to genetically determined difference in uptake of nutrient (Uddin *et al.,* 2009). Uddin *et al.* (2009) reported that, the differences in 1,000-grain weight of these cultivars might be due to hereditary superiority, growth rate and potential of yield. The enhancement in mung bean yield with combined application or rhizobium and phosphorus might be owing to increase in phosphorus availability that lead to better translocation of photosynthesis towards sink with consequent improvement in yield attributes (Muhammad *et al*., 2004).

The results of the one-year study indicates that selection of suitable variety (Mai-08) when combined with Appropriate dose resulted in highest growth yield attributes & yield mung bean.

REFERENCES

Ali, M.Z., Khan, M.A.A., Rahaman, A.K.M.M., Ahmed, M. and Ahsan, A.F.M.S. 2010. Study on seed quality and performance of some mung bean varieties in Bangladesh. *International. Journal of Experimental Agric*ulture **1**(2): 10–15.

Ayub, M. A., Tanveer, M.A., Choudhry, M.M.Z. Amin and Murtaza, G. 1999. Growth and yield response of mung bean (*Vigna radiata* L.) cultivars at varying levels of nitrogen. *Pakistan Journal of Biological Science* **2**: 1,378–1,380.

Bourgault, M., Madramootoo, C.A., Webber, H.A., Stulina, G., Horst, M.G. and Smith, D.L. 2010. Effects of deficit irrigation and salinity stress on common bean (*Phaseolus vulgaris* L.) and mung bean [*Vigna radiata* (L.) R. Wilczek] grown in a controlled environment. *Journal of Agronomy and Crop Science* **196**: 262–272.

Choudhary, A.K., Rana, D.S., Bana, R.S., Pooniya, Vijay, Dass, A., Rana, K.S. and Kaur, R. 2015. *Agronomy of oilseed and pulse crops*. ICAR-Indian Agriculture Research Institute, New Delhi.ISBN978-9383168-21–7.

El-Adawy, T.A. 1996. Chemical, nutritional and functional properties of mung bean protein isolate and concentrate. *Menufiya Journal of Agricultural Research* **21**(3): 657–672.

Hamim, H. 2016. Effect of varying potassium levels on productivity and profitability of Kharif mung bean (*Vigna radiata* L.) in semi-arid conditions of Kandahar. M.Sc. Thesis, Afghanistan National Agricultural Sciences and Technology University, Afghanistan, p. 51.

Jahish, F. 2016. Effect of different phosphorus levels on growth and yield of mung bean (*Vigna radiata* L.), M.Sc. Thesis, Afghanistan National Agricultural Sciences and Technology University, Afghanistan.

Kumar, R., Singh, Y.V., Singh, S., Latare, A.M., Mishra, P.K. and Supriya. 2012. Effect of phosphorus and sulphur nutrition on yield attributes, yield of mung bean [*Vigna radiata* (L.) Wilczek]. *Journal of Chemical and Pharmaceutical Research* **4**(5): 2,571–2,573.

Mitra, S., Rhattacharya, S.K. Datta, M. and Banik, S. 1999. Effect of variety, rock phosphate and phosphate solubilizing bacteria on growth and yield of green gram in acid soils of Tripura. *Environment Ecology* **17**: 926–930.

Muhammad, D., Gurmani, A.H. and Matiullah, K. 2004. Effect of phosphorus and *Rhizobium* inoculation on the yield and yield components of mung bean under the rainfed condition of D.I. Khan. *Sarhad Journal of Agriculture* **20**(4): 575–582.

Nadeem, A., Muhmmad, Amjad and Muhammad Akbar, Anjum. 2003. Growth and yield response to pea (*Pisum sativum* L.) Crop to phosphorus and potassium application. *Pakistan Journal of Agriculture Science* **40**(3–4).

Noorzai, A., Choudhary, A.K., Bana, R.S. and Prasad, R. 2017. Growth behaviour, productivity and profitability of promising mung bean varieties in semi-arid region of Afghanistan. *Annual Agriculture Research* **38**(1): 78–86.

Prasad, K., Kumar, S., Pyare, R. and Rathi, J.P.S. 2015. Effect of FYM and biofertilizer in conjunction with inorganic fertilizer on growth, yield and profit of chickpea (*Cicer arietinum* L.). *Plant Archives* **5**(2): 609–612.

Singh, G., Sekhon, H.S., Sharma, Poonam and Bains, T.S. 2007. Response of mung bean varieties to plant populations in summer season. *Indian Journal of Food Legumes* **20**(10): 115–116.

Tesfaye, M., Liu, J., Allan, D.L. and Vance, C.P. 2007. Genomic and genetic control of phosphate stress in legumes. *Plant Physiology* **144**: 594–603.

Uddin, M.S., Amin, A.K., Ullah, M.J. and Asaduzzman, M. 2009. Interaction effect of variety and different fertilizers on the growth and yield of summer mung bean. *American-Eurasian Journal of Agronomy* **2**(3): 180–184.

Yadav, C., Dindayal, L. and Singh, V. 2011. Effect of yield and quality of green gram varieties by foliar spray of urea and seed rate. *Plant Archives* **11**(1): 289–291.

Indian Journal of Agronomy **68** (4): 455–458 (December 2023)

Research Communication

Optimization of phosphorus levels for enhancing groundnut productivity under different land configuration in semi-arid ecologies of Afghanistan

KHALILULLAH KHALEEQ[1], S.S. RATHORE[2], NAJIBULLAH HEMMAT[3], KAPILA SHEKHAWAT[4], SMRUTI RANJAN PADHAN[5], SUBASH BABU[6] AND R.K. SINGH[7]

Afghanistan National Agricultural Sciences and Technology University, Kandahar, Afghanistan

Received: May 2023; Revised accepted: November 2023

ABSTRACT

The present investigation entitled "Optimization of phosphorus levels for groundnut under different land configuration in Afghanistan" was carried out at Afghanistan National Agricultural Science and Technology University (ANASTU), Kandahar Province, Afghanistan during spring season of 2020. The experiment was conducted in a split-plot design with 15 treatment combinations and three replications. The main-plot consised of land configurations, viz. ridge and furrow (RF), broad bed and furrow (BBF) and flatbed (FB), while the sub-plots comprised of phosphorus levels, viz. absolute control, 20, 40, 60 and 80 kg P_2O_5/ ha. The results revealed that the plant growth in terms of dry matter accumulation (above ground and below ground) and number of branches/plant were maximum in BBF, followed by FB and minimum in RF. Adoption of BBF also recorded significantly higher pod yield (2,987 kg/ha) and harvest index (31.0). With respect to P levels, application of 60 kg P_2O_5/ha produced significantly higher pod yield (3,363 kg/ha), biological yield (13,157 kg/ha) than other P_2O_5 levels. Therefore, growing of groundnut on BBF with application of 60 kg P_2O_5/ ha was found beneficial for achieving higher production and productivity under Afghanistan conditions.

Key words: Broad bed and furrow, Flat-bed, Pod yield, Ridge and furrow, Root dry matter

Groundnut (*Arachis hypogaea* L.) is an economically-important oilseed, feed, and food crop, which is widely cultivated in tropical and sub-tropical regions of the world (Ajay *et al*., 2023). It is an annual crop primarily grown for its protein rich kernel and edible oil. Planting geometry has a plentiful effect on the groundnut growth and productivity as it decides the plant architecture and its ability to use adequate resources. Groundnuts can be planted using a number of methods which include planting on flat ground (FG), earthing up after plant on flat ground, planting on raised bed and planting on ridges (Rathore *et al.,* 2014, Meena *et al*., 2022). However, groundnut productivity is low due to flatbed cultivation which hampers adequate pod development. Also, flat beds resulted in higher evaporation resulting in drought stress in groundnut. Therefore, modifying land configurations like raised bed technique tends to enhance growth and productivity of crops by reducing energy and carbon dynamics (Rathore *et al*., 2020). Phosphorus (P) is needed by groundnut plants for efficient root development for nodulation. P is a constituent of nucleic acid and thus aids in stimulation of root growth and nodule activity. Kamara *et al*. (2011) reported an increase in biomass of groundnut after the application of P fertilizer and attributed it to the availability of soluble phosphate that enhanced extensive root development. Adequate phosphorus nutrition has been attributed to enhanced yield and income of groundnut farmers because of the role played by phosphorus in the physiological process of plant growth and development. Hence, the proper optimization of P doses in different land configuration techniques is having a vital importance in deciding the productivity of groundnut. Therefore, the current study was carried out to investigate the effects of land configurations and P fertilizers on the performance of groundnut.

A field experiment was carried out at the ANASTU farm, Kandahar Province, Afghanistan (31°30'N, 65°50'E, 1010 m above mean sea-level) during spring season of 2020 to evaluate the different level of phosphorus for groundnut in different land configuration techniques. The

Based on a part of M.Sc. Thesis of the first author submitted to the Afghanistan National Agricultural Sciences and Technology University, Kandahar, Afghanistan in 2020 (unpublished)

[1]**Corresponding author's Email:** khalil.khaleeq@gmail.com
[1,3]M.Sc. Scholar Faculty of Plant Sciences, Afghanistan National Agricultural Sciences and Technology University, Kandahar, Afghanistan; [2]Head; [4,6]Senior Scientist, Division of Agronomy, ICAR-Indian Agricultural Research Institute, Pusa, New Delhi 110 012; [5]Seledi, Binka, Subaranapur, Seldi, Odisha

experimental site has a subtropical steppe/low-latitude semi-arid hot climate. The maximum and minimum temperature during the experiment was 43°C and 15 °C, respectively with annual average precipitation of 190.6 mm. The experiment was laid out in a split-plot design with 15 treatment combinations each replicated thrice. The main-plots consisted of three land configuration techniques [ridge and furrow (RF), broad bed and furrow (BBF) and flatbed (FB)], while the sub plots consisted of variable P levels (0, 20, 40, 60 and 80 kg P_2O_5/ha). Apart from the treatments, other standard agronomic crop management practices were followed across the treatments. Growth parameters were taken by taking the average of five tagged plants. The recorded data were subjected to statistical analysis using ANOVA for the split-plot design.

The results showed that adoption of different land configuration and optimization of phosphorus significantly influenced on growth attributes of groundnut (Table 1). The adoption of BBF exhibited maximum branches/plant which remained significantly higher over other methods, and the minimum branches/plant were produced under FB at all crop growth stages (30, 60, 90 DAS and harvest). With respect to P levels, the application of 40-80 kg P_2O_5/ha performed equally and produced maximum branches/plant as compared to 20 kg P_2O_5/ha and absolute control at 30 DAS. At 60 DAS, 40 kg P_2O_5/ha noted significantly more branches/plant followed by 80 kg P_2O_5/ha. At 60 DAS and at harvest, the application of 80 kg P_2O_5/ha recorded significantly higher branches/plant, being at par with 60 and 40 kg P_2O_5/ha. However, the dry matter accumulation was higher at 60 kg P_2O_5/ha, which remained at par with 80 kg P_2O_5/ha. Nazir *et al*. (2022) reported that the P levels failed to affect number of main branches/plant significantly, but the application of 60 kg P_2O_5/ha produced slightly higher main branches/plant, mainly because of synchronous P supply and demand by the crop. Choudhary *et al*. (2011) carried out a field study on loam sand and reported that application of 20 kg N+40 kg P_2O_5/ha to cowpea produced significantly higher dry matter/meter row length, branches/plant, plant height, total chlorophyll content and number and weight of root nodules per plant over lower doses of N and P.

Dry matter accumulation (DMA) was also influenced significantly at 60, 90 DAS and also at harvest stage. No significant effect of land configurations was recorded on DMA at 30 DAS, but at 60 DAS, the higher DMA was recorded under BBF (Table 1). At 90 DAS, RF was recorded with significantly higher DMA (12.5 g/plant) whereas at harvest, the higher DMA (45.2 and 42.3 g/plant, respectively) was recorded under RF and BBF and the minimum was noticed under FB (29.5 g/plant). At 60 DAS, 40 kg P_2O_5 resulted in maximum dry matter (7.11 g/plant), whereas the minimum was recorded under control (4.17 g/plant). A similar trend of results was also recorded at harvest as noted at 90 DAS. Nazir *et al*., (2022) reported that the application of 60 kg P_2O_5/ha resulted in significantly higher plant height, leaf area index at 90 DAS and plant dry matter accumulation as compared to control. Whereas, at 90 DAS, higher (0.78 g) and lower (0.62 g) root dry matter accumulations were recorded with the application of 80 kg P_2O_5/ha and control plots, respectively. Choudhary *et al*. (2011) reported that P is needed by plants for efficient root development for nodulation and also phosphorus is a constituent of nucleic acid and thus aids in stimulation of root growth and nodule activity.

Among yield attributes, pods weight/plant increased under BBF (31.51 g), but it remained at par (Pd"0.05) with RF (30.36 g). Likewise, pods/plant (23.32) and 100 seed weight (77.89 g) were recorded higher with adoption of BBF over other land configurations (Table 2). The trend in

Table 1. Effect of land configuration and phosphorus levels on growth attributes of groundnut

Treatment	Branches/plant				Plant dry matter accumulation (g/plant)				Root dry matter accumulation (g/plant)		
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	At harvest
Land configuration											
RF	3.8^{b}	5.8^{b}	6.8^{b}	8.0^{c}	0.6	5.4^{b}	12.5^{a}	45.2^{a}	0.23^{a}	0.53^{b}	0.74^{a}
BBF	4.0^{a}	6.1^{a}	7.8^{a}	10.0^{a}	0.7	6.4^{a}	10.0^{b}	42.3^{a}	0.21^{a}	0.62^{a}	0.73^{a}
FB	3.7^{b}	5.6^{b}	7.7^{a}	8.5^{b}	0.7	5.1^{b}	8.0^{c}	29.5^{b}	0.18^{a}	0.34c	0.66^{b}
Phosphorus levels (kg P_2O_5/ha)											
Control	3.5^{b}	4.9^{d}	6.9^{c}	6.7^{c}	0.6	4.1^{c}	7.8^{c}	33.1^{c}	0.06^{d}	0.31^{b}	0.62^{c}
20	3.6^{b}	5.4^{cd}	7.2^{bc}	8.3^{b}	0.7	4.7^{c}	8.0^{c}	31.8^{c}	0.09^{c}	0.34^{b}	0.64^{c}
40	4.0^{a}	6.6^{a}	7.6^{ab}	9.5^{a}	0.8	7.1^{a}	9.6^{b}	35.8^{b}	0.14^{a}	0.44^{a}	0.73^{ab}
60	4.0^{a}	5.8^{bc}	7.8^{a}	9.5^{a}	0.6	5.5^{bc}	10.9^{a}	39.9^{a}	0.11^{b}	0.52^{a}	0.68^{b}
80	4.0^{a}	6.4^{ab}	7.8^{a}	10.1^{a}	0.6	6.8^{ab}	10.4^{a}	43.5^{a}	0.11^{b}	0.42^{a}	0.78^{a}

*RF: Ridge & furrow; BBF: Broad bed & furrow; FB: flat bed, similar letter within the column depicts non-significance at 5% probability level

Table 2. Effect of land configuration and optimization of phosphorus levels on yield and yield attributes of groundnut

Treatment	Pod weight/ plant (g)	Pod length (cm)	Kernel/ pod	Pods/ plant	100 -seed weight (g)	Pod yield (kg/ha)	Biological yield (kg/ha)	Harvest index	Shelling (%)
Land configuration									
RF	28.5[b]	3.5[a]	1.7[a]	19.2[b]	66.7[c]	2,912[a]	9,009[b]	33[a]	66.4
BBF	31.5[a]	3.5[a]	1.8[a]	23.3[a]	77.8[a]	2,987[a]	9,673[b]	31[a]	67.8
FB	30.3[ab]	3.5[a]	1.7[a]	21.0[b]	71.9[b]	2,578[b]	11,344[a]	24[b]	65.4
Phosphorus levels (kg P_2O_5/ha)									
Control	28.1[b]	2.8[d]	1.6[c]	18.7[c]	65.3[b]	2,026[d]	7,198[e]	29[b]	65.3b[c]
20	27.9[b]	3.4[c]	1.7[bc]	18.1[c]	73.0[a]	2,631[c]	8,950[d]	29[ab]	65.6ab[c]
40	29.8[b]	3.6[b]	1.8[ab]	22.2[b]	72.5[a]	3,163[ab]	9,776[c]	33[a]	69.2[ab]
60	34.4[a]	3.9[a]	1.9[a]	25.6[a]	73.9[a]	3,363[a]	13,157[a]	26[b]	71.5[a]
80	30.2[b]	3.9[a]	1.7[bc]	21.1[b]	76.1[a]	2,945[bc]	10,965[b]	29[b]	61.0[c]

*RF, Ridge & furrow; BBF, Broad bed & furrow; FB, flat bed, similar letter within the column depicts non-significance at 5% probability level

groundnut pod and biological yield was also noted similar to yield attributes. The shelling percentage ranged 61.0 to 71.5%, with maximum being in BBF with 60 kgP_2O_5/ha and decreased with further increase in P_2O_5 levels (Table 2). The reasons for this decline with increase in P level might be due to antagonistic effects of P with other nutrients in the soil (Rathore *et al*., 2014). Significantly higher values yield (11,344 kg/ha) and seed yield/plant (0.21 kg) were noted under BBF than other land configurations. Adoption of BBF and RF also recorded significantly higher pod yield (2987 and 2912 kg/ha, respectively) and harvest index (31.0 and 33.0, respectively) and both remained statistically at par with each other. The extent of yield increment with BBF and RF over FB was 15.87 and 12.96%, respectively. The BBF provided a loose soil mass with adequate soil moisture which heightened the crop growth attributes. These conditions favorably influenced the easy peg penetration, pod development and thereby the shelling percentage, thus enabling the plants to express their potential to large extent (Heba *et al*., 2021).

Likewise, application of 60 kg P_2O_5/ha produced maximum pod weight/plant (34.46 g) and pods/plant (25.6) and proved significantly superior over other treatments. Increased pod length was noted in 60-80 kg P_2O_5/ha over other of phosphorus levels. Conversely, maximum kernel/pod was noted with 60 and 40 kg P_2O_5/ha which found significantly similar with each other. Application of 60 kg P_2O_5/ha produced significantly higher pod yield (3363 kg/ha), biological yield (13,157 kg/ha) and being at par with 40 kg P_2O_5/ha except biological yield which recorded significantly different from other levels of Phosphorus levels. The remarkable increase in pod yield with corresponding value of 65.99% was noted with the application of 60 kg P_2O_5/ha over control. With respect to 100 seed weight maximum value was recorded with 80 kg P_2O_5/ha and remained significantly static with other levels of phosphorus except control which found with significantly lowest 100 seed weight. Similarly, Nazir *et al.* (2022) reported that application of 60 kg P_2O_5/ha significantly increased yield attributes as well as pods yield, kernel yield, haulm yield and biological yield.

From the current study, it may be concluded that the adoption of BBF along with 60 kg/ha P_2O_5 will be beneficial for increasing the growth and productivity of groundnut in Afghanistan and similar other agro-ecologies.

REFERENCES

Ajay, B.C., Kumar, N., Kona, P., Gangadhar, K., Rani, K., Rajanna, G.A. and Bera, S.K. 2023. Integrating data from asymmetric multimodels can identify droughtresistant groundnut genotypes for drought hotspot locations. *Scientific Reports* **13**:12705. https://doi.org/10.1038/s41598-023-38581-0

Choudhary, G.L. and Yadav, L.R. 2011. Effect of fertility level and foliar nutrition on cowpea productivity. *Journal of Food Legume* **24**(1): 67–68.

Heba, M.N., Rana, D.S., Choudhary, A.K., Dass, A., Rajanna, G.A., and Pande, P. 2021. Improving productivity, quality and biofortification in groundnut (Arachis hypogaea L.) through sulfur and zinc nutrition in alluvial soils of the semi-arid region of India. *Journal of Plant Nutrition* **44**(8): 1151–1174. DOI: 10.1080/01904167.2020.1849289

Kamara, A.Y., Ekeleme, F., Kwari, J.D., Omoigui, L.O. and Chikoye, D. 2011. Phosphorus effect on growth and yield of groundnut varieties in the tropical savanna of North Eastern Nigeria. *Journal of Tropical Africa* **49**(2): 24–30.

Meena, H.N., Ajay, B.C., Rajanna, G.A., Yadav, R.S., Jain, N.K. and Meena, M.S. 2022. Polythene mulch and potassium application enhances peanut productivity and biochemical traits under sustained salinity stress condition. *Agricultural Water Management* **273**: 107903. https://doi.org/10.1016/j.agwat.2022.107903

Munda, G.C., Patel, D.P. and Islam, M. 2004. Effect of macro and micro nutrient on growth and yield of groundnut. *Annals of Plant Physiology* **18**(1): 9–12.

Nazir, R., Sayedi, S.A., Zaryal, K., Khaleeq, K., Godara, S., Bamboriya, S.D. and Bana, R.S. 2022. Effects of phosphorus application on bunch and spreading genotypes of groundnut *Journal of Agriculture and Ecology* **14**: 26–31.

Rathore. S.S., Kapila, Shekhawat, and G.A. Rajanna, 2020. Land configurations in surface drip irrigation for enhancing productivity, profitability and water-use efficiency of Indian mustard (Brassica juncea) under semi-arid conditions. *Indian Journal of Agricultural Sciences* **90**(8): 1,538–1,543.

Rathore, S.S., Chaudhary, D.R., Vaisya, L.K., Shekhawat, Kapila and Bhatt, B.P. 2014. Schoenite and potassium sulphate: Indigenous potassic fertilizer for rainfed groundnut (Arachis hypogaea L.). *Indian Journal of Traditional Knowledge* **13**(1): 222–226.

LIST OF LIFE MEMBERS OF ISA 2023

Executive Council of the Indian Society of Agronomy extends hearty welcome to the life members of 2023 of Indian Society of Agronomy and solicits active participations/contributions for the progress of the Society.

Shiva Dhar
Secretary,
The Indian Society of Agronomy

1. P. Amara Jyothi, **AP/2023/3331**, Srikakulam, Andhra Pradesh
2. Sidhartha Naik, B.S.S., **AP/2023/3332**, Guntur, Andhra Pradesh
3. Srinivasa Rao, M.M.V. **AP/2023/3333**, Vizianagaram, Andhra Pradesh
4. Tejeswara Rao, Kottana, **AP/2023/3334**, Vizianagaram, Andhra Pradesh
5. Bharadwaj, Krishna, **A/2023/3335**, Diphu, Assam
6. Borah Debasish, **A/2023/3336**, Lalpool, Assam
7. Borah, Santanu Kaushik, A/2023/**3337**, Jorhat, Assam
8. Talukdar, Lipika, **A/2023/3338**, Jorhat, Assam
9. Goudar, Pavankumar, **ArP/2023/3339**, Pasighat, Arunachal Pradesh
10. N., Premaradhya, **ArP/2023/3340**, Pasighat, Arunachal Pradesh
11. Ansari, Majhrool Hak, **B/2023/3341**, Buxar, Bihar
12. Naz, Shaheen, **B/2023/3342**, Buxar, Bihar
13. Verma, Kajal, **B/2023/3343**, Gaya, Bihar
14. Mirjha, Swati Thakur, **CG/2023/3344**, Bhatapara, Chhattisgarh
15. Bharti, Rupam, **ND/2023/3345**, New Delhi
16. Borate, Rohit Bapurao, **ND/2023/3346**, New Delhi
17. G.D., Sanketh, **ND/2023/3347**, New Delhi
18. Gairola, Ananya, **ND/2023/3348**, New Delhi
19. Kumar, Vipin, **ND/2023/3349**, New Delhi
20. Lakhana, Kamlesh Kumar, **ND/2023/3350**, New Delhi
21. Manu, S.M., **ND/2023/3351**, New Delhi
22. Meena, Deepak Kumar, **ND/2023/3352**, New Delhi
23. Nithinkumar, Kadagonda, **ND/2023/3353**, New Delhi
24. Patel, Anjali, **ND/2023/3354**, New Delhi
25. Patel, Shashank, **ND/2023/3355**, New Delhi
26. Prajapati, Sunil Kumar, **ND/2023/3356**, New Delhi
27. Rawat, Satyam, **ND/2023/3357**, New Delhi
28. Saikia, Nilutpal, **ND/2023/3358**, New Delhi
29. Sharma, Diksha, **ND/2023/3359**, New Delhi
30. Sharma, Tarun, **ND/2023/3360**, New Delhi
31. Shukla, Gaurav, **ND/2023/3361**, New Delhi
32. Bommayasamy, N., **Goa/2023/3362**, Old Goa, Goa
33. Kumar, Dinesh, **Goa/2023/3363**, Old Goa, Goa
34. Chaudhari, Niteshkumar, **G/2023/3364**, Anand, Gujarat
35. Chaudhari, Pankajkumar Rameshbhai, **G/2023/3365**, Sardarkrushinagar, Gujarat
36. Chaudhari, Vishakha, **G/2023/3366** Anand, Gujarat
37. Muchhadiya, Ravindra M., **G/2023/3367** Junagadh, Gujarat
38. Patel, Ritubahen, **G/2023/3368**, Sardarkrushinagar, Gujarat
39. Patel, Vipul Bhai, **G/2023/3369**, Anand, Gujarat
40. Thakur, Mangesh Ravindra, **G/2023/3370**, Bharuch, Gujarat
41. Dhasmana, V.K., **H/2023/3371**, Gurugram Haryana
42. Garg, Kamal, **H/2023/3372**, Karnal, Haryana
43. Kumar, Birendra, **H/2023/3373**, Karnal, Haryana
44. Kumar, Jitender, **H/2023/3374**, Rewari, Haryana
45. Satyajeet, **H/2023/3375**, Rewari, Haryana
46. Supriya, **H/2023/3376**, Karnal, Haryana
47. Manhas, Shilpa, **HP/2023/3377**, Palampur, Himachal Pradesh
48. Sharma, Saurav, **HP/2023/3378**, Sirmour, Himachal Pradesh
49. Biradar, Iranagouda, **K/2023/3379**, Bagalkot, Karnataka
50. Mallikarjuna, B.O., **K/2023/3380,** Davanagere, Karnataka
51. Soumya, T.M., **K/2023/3381**, Shivamogga, Karnataka
52. Ajmal, K.K., **KE/2023/3382**, Tazhe Muttil, Kerala
53. Surekha, **KE/2023/3383**, Kasargod, Kerala
54. Kumar Vinod, **MP/2023/3384**, Distt. Naramadapuram, Madhya Pradesh
55. M.N., Harish, **MP/2023/3385**, Jabalpur Madhya Pradesh
56. Mohaniya, Lakhan Singh, **MP/2023/3386**, Gwalior, Madhya Pradesh
57. Raghuwanshi, Om Prakash Singh, **MP/2023/3387**, Sagar, Madhya Pradesh
58. Sahu, Muni Pratap, **MP/2023/3388**, Jabalpur, Madhya Pradesh
59. Sharma, Aparna, **MP/2023/3389**, Jabalpur, Madhya Pradesh
60. Singh, Vikash, **MP/2023/3390**, Jabalpur, Madhya Pradesh
61. Tiwari, Aditya, **MP/2023/3391**, Satna, Madhya Pradesh
62. Verma, Badal, **MP/2023/3392**, Jabalpur, Madhya Pradesh
63. Bhusari, Sandip, **MS/2023/3393**, Rahuri, Maharashtra
64. Diksha, Tajane, **MS/2023/3394**, Nagpur, Maharashtra
65. Talathi, Manoj, **MS/2023/3395**, Distt. Raigad, Maharashtra
66. Teli, Kashinath Gurusiddappa, **MS/2023/3396**, Rahuri, Maharashtra
67. Varnekar, Kiran, **MS/2023/3397**, Rahuri, Maharashtra
68. Biswakarma, Niraj, **Meg/2023/3398**, Umaim, Meghalaya
69. Wanniang, Samborlang K., **Meg/2023/3399**, Tura, Meghalaya
70. Jena, Jagadish, **O/2023/3400**, Bhubaneswar, Odisha
71. Mangaraj, Satyabrata, **O/2023/3401**, Sonepur, Orissa
72. Sahoo, Upasana, **O/2023/3402**, Paralakhemundi, Odisha
73. Shankar, Tanmoy, **O/2023/3403**, Paralakhamundi, Odisha
74. Kaur, Gurpreet, **Pb/2023/3404**, Ludhiana, Punjab
75. Choudhary, Monika, **R/2023/3405**, Udaipur, Rajasthan
76. Dhakad, Uditi, **R/2023/3406**, Kota, Rajasthan
77. Jajoria, Dinesh Kumar, **R/2023/3407**, Jobner, Rajasthan
78. Meena, Shalini, **R/2023/3408**, Kota, Rajasthan
79. Yadav, Ranveer Kumar, **R/2023/3409**, Bikaner, Rajasthan
80. Ajaykumar, R., **TN/2023/3410**, Pollachi, Tamil Nadu
81. Samandam, Saranraj Thirugnana, **TN/2023/3411**, Ariyalur, Tamil Nadu
82. Chunchu, Suchith Kumar, **TEL/2023/3412**, Warangal, Telangana
83. Oddulavamshi, **TEL/2023/3413**, Hyderabad, Telangana
84. Ramulu, Chandragiri, **TEL/2023/3414**, Hyderabad, Telangana
85. Sowjanya, Aleti, Jagadish, **TEL/2023/3415**, Hyderabad, Telangana
86. Bhushan, Chandra, **UP/2023/3416**, Varanasi, Uttar Pradesh
87. Guleria, Gunjan, **UP/2023/3417**, Jhansi, Uttar Pradesh
88. Kushwah, Manoj, **UP/2023/3418**, Varanasi, Uttar Pradesh
89. Mohd. Arif **UP/2023/3419**, Meerut, Uttar Pradesh
90. Perramalyan, Panneerselvam, **UP/2023/3420**, Varanasi, Uttar Pradesh
91. Prakash, Ved, **UP/2023/3421**, Varanasi, Uttar Pradesh
92. Sanodiya, Lalit Kumar, **UP/2023/3422**, Naini Prayagraj, Uttar Pradesh
93. Singh, Ambuj Kumar, **UP/2023/3423**, Varanasi, Uttar Pradesh
94. Singh, Bal Veer, **UP/2023/3424,** Kanpur, Uttar Pradesh
95. Singh, Naveen Kumar, **UP/2023/3425**, Pratapgarh, Uttar Pradesh
96. Singh, S.B., **UP/2023/3426**, Banda, Uttar Pradesh
97. Singh, Utkarsh, **UP/2023/3427**, Ayodhya, Uttar Pradesh
98. Singh, Vishal, **UP/2023/3428**, Mau, Uttar Pradesh
99. Verma, Sunil Kumar, **UP/2023/3429**, Varanasi, Uttar Pradesh
100. Yadav, Santosh Kumar, **UK/2023/3430**, Pantnagar, Uttarakhand
101. Dey, Prithwiraj, **WB/2023/3431**, Kharagpur, West Bengal
102. Kundu, Rajib, **WB/2023/3432**, Nadia, West Bengal
103. Paramanik, Bappa, **WB/2023/3433**, Balurghat, West Bengal
104. Poddar, Ratneswar, **WB/2023/3434**, Nadia, West Bengal
105. Sarkar, Ayan, **WB/2023/3435**, Coochbehar, West Bengal

LIST OF REVIEWERS OF INDIAN JOURNAL OF AGORNOMY – 2023

I sincerely acknowledge with thanks to the contributions of the reviewers of Indian Journal of Agronomy, which has enabled us to bring the journal well in time and request for the similar contributions in future too.

Shiva Dhar
Secretary
The Indian Society of Agronomy

Dr A.V. Ramanjaneyulu , PJTSAU, Siddipet, Telangana
Dr Amit Kumar Jha, JNKVV, Jabalpur, M.P.
Dr Amit Kumar, ICAR RC for NEH, Gangtok, Sikkim
Dr Anchal Das, ICAR-IARI, New Delhi
Dr Anil K. Choudhary, Shimla, Himachal Pradesh
Dr Anju Bijarnia, Kota, Rajasthan
Dr Anup Das, ICAR-RC for NEH Region, Agartala, Tripura
Dr Biswajit Pramanik, Dr. RPCAU, Pusa Samastipur, Bihar
Dr Chandeshwar Tiwari, Pauri Garhwal, Uttarakhand
Dr Dasharath Prasad, Shi Ganganagar, Rajasthan
Dr Devideen Yadav, IISWC, Dehradun Uttarakhand
Dr Dibakar Mahanta, ICAR-IARI, New Delhi
Dr Dileep Kumar, IISR, Lucknow, U.P.
Dr Dinesh Jinger, ICAR-IISWC, Anand, Gujarat
Dr Ekta Joshi, RVSKVV, Gwalior, M.P.
Dr G. Pratibha, ICAR-CRIDA, Hyderabad, Telangana
Dr G.A. Rajanna, ICAR-IARI, New Delhi
Dr Hari Ram, PAU, Ludhiana, Punjab
Dr Jayesh Singh, PAU, Ludhiana, Punjab
Dr K. Sankaranarayanan, ICAR-CICR, Coimbatore, T.N.
Dr K.A. Gopinath, CRIDA, Hyderabad, Telangana
Dr Kailash Prajapat, ICAR-CSSRI, Karnal, Haryana
Dr Kapila Shekhawat, ICAR-IARI, New Delhi
Dr M. Ameena, COA, Vellayani, Trivandrum, Kerala
Dr M. Malla Reddy, PJTSAU, Hyderabad, Telengana
Dr M.A. Ansari, IIFSR, Modipuram, Meerut
Dr M.A. Shankar, Bangalore, Karnataka
Dr M.C. Kalita, Guwahati, Assam
Dr M.K. Rapolu, IIRR, Rajendranagar Hyderabad, A.P.
Dr Mangal Deep Tuti, ICAR-IIRR, Hyderabad, Telangana
Dr Mohammad Hashim, Pusa Samastipur, Bihar
Dr Mona Nagargade, ICAR-IARI, New Delhi
Dr Monika Shukla, ICAR-CSSRI, Bharuch, Gujarat
Dr Mukesh Choudhary, ICAR-IGFRI, Jahansi, U.P.
Dr Mukesh Kumar, RPCAU, Pusa Samastipur, Bihar
Dr N. Ravisankar, ICAR-IIFSR, Modipuram, U.P.
Dr N.K. Jain, ICAR-IARI, New Delhi
Dr N.K. Jat, CAZRI, Jodhpur, Rajasthan
Dr Narendra Kumar, ICAR-IIPR, Kanpur, U.P.
Dr Neetu Sharma, SKUAST-J, Chatha, Jammu, J&K
Dr Parveen Kumar, ICAR-CCARI, Goa
Dr Parvin Kumar Upadhyay, ICAR, New Delhi
Dr Prabhu Govindasamy, ICAR-IARI, New Delhi
Dr R.A. Jat, ICAR-AICRP on Groundnut, Junagadh, Gujarat
Dr R.S. Bana, ICAR-IARI, New Delhi
Dr Raghuvendra Madar, ICAR-IISR, Indore, M.P.
Dr Raghuvendra Singh, ICAR-IIPR, Kanpur, U.P.
Dr Raihana Habib Kanth, SKUAST, J & K
Dr Rajeew Shukla, GBPUA&T, Pantnagar, Uttarakhand
Dr Rajendra Prasad Meena, VPKS, Almora, Uttarakhand
Dr Rajiv Kumar Singh, ICAR-IARI, New Delhi
Dr Rashmi Yadav, NBPGR, New Delhi
Dr Rishi Raj, ICAR-IARI, New Delhi
Dr S.C. Tripathi, ICAR-IIWBR, Karnal, Haryana
Dr S.K. Sarangi, ICAR-CSSRI, 24 Parganas, W.B.
Dr S.P.S. Tanwar, CAZRI, Jodhpur, Rajasthan
Dr S.S. Rathore, ICAR-IARI, New Delhi
Dr S.S. Walia, PAU, Ludhiana, Punjab
Dr Sanjay Kumar Yadav, ICAR-IISR, Lucknow, U.P.
Dr Subhash Babu, ICAR-IARI, New Delhi
Dr Sunil Kumar, ICAR-IGFRI, Jhansi, U.P.
Dr Sushmita Munda, ICAR-NRRI, Cuttack, Odisha
Dr Swarna Ronanki, ICAR-IIMR, Hyderabad, Telangana
Dr T.P. Saikia, Golaghat, Assam
Dr Teekam Singh, ICAR-IARI, New Delhi
Dr V. Paramesh, ICAR-CCARI, Goa
Dr V. Ramamurthy, ICAR-NBSS&LUP, Bangalore, Karnataka
Dr V. Visha Kumari, ICAR-CRIDA, Hyderabad, Telangana
Dr V.K. Singh, GBPUA&T, Pantnagar
Dr Vishal Tyagi, ICAR-IARI, New Delhi
Dr Yogeshwar Singh, RLB CAU, Jhansi, U.P.