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Research Paper

Effect of seed rate and integrated nutrient management on growth, yield and economics of direct seeded hybrid rice (*Oryza sativa*)

HEMRAJ MEENA[1], M.K. SINGH[2], MEENA RANI[3] AND R.N. MEENA[4]

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

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ABSTRACT

A field experiment was conducted during the rainy seasons of 2016 and 2017 at Agricultural Research Farm, Banaras Hindu University, Varanasi, Uttar Pradesh, to evaluate the effect of integrated nutrient management and seed rate on growth, yield and economics of direct-seeded hybrid rice (*Oryza sativa* L.). The treatments comprised 3 seed rates (16 kg, 20 kg and 24 kg/ha) and 5 nutrient management, i.e. 100% recommended dose of fertilizer (RDF) through inorganic fertilizer, 100% RDF through inorganic fertilizer + $ZnSO_4.7H_2O$ 25 kg/ha followed by (*fb*) 0.2% $FeSO_4$ and 0.2% Borax foliar spray at 20 and 40 days after sowing (DAS), 75% recommended dose of nitrogen (RDN) through inorganic fertilizer + 25% N through FYM, 50% RDN through inorganic fertilizer + 50% N through FYM, and 75% RDN through inorganic fertilizer + 25% N through vermicompost. The experiment was laid out in split plot design with 3 replications. Rice hybrid sown at seed rate of 20 kg/ha showed superior performance in respect of tillers/m^2, dry-matter accumulation, leaf-area index (LAI), soil plant analysis development (SPAD) value and yield parameters, i.e. grain and straw yields, net returns and benefit–cost ratio as compared to seed rate of 16 and 24 kg/ha. Amongst the integrated nutrient management options, an application of 50% RDN by urea + 50% N by FYM resulted in better performance, being comparable with those of 75% RDN through inorganic fertilizer + 25 % N through FYM. However, 100% RDF through inorganic fertilizer recorded the lowest growth and yield parameters. Seed rate of 20 kg/ha along with 50% RDN through inorganic fertilizer + 50% N through FYM was found to be a better option for obtaining optimum crop plants and nutrient-management practices in direct-seeded hybrid rice.

Key word **:** Direct-seeded hybrid rice, Economics, Integrated nutrient management, Seed rate, Yield

Rice is cultivated world-wide over an area of about 160.6 million ha. In India, area under cultivation of rice is around 44 million ha with production of 109.70 million tonnes during 2016-17 (DES, 2018). Uttar Pradesh is the largest rice-growing state in India, with an area of about 5.87 million ha and production of 12.22 million tonnes (DES, 2015). Direct-seeding technique offers a useful option to reduce the limitations of transplanted rice. Direct-seeded rice occupies 26% of the total rice area in South Asia (Gupta *et al.,* 2006). Direct seeding of rice avoids puddling, does not need continuous submergence, and thus reduces the overall water demand for rice culture. When rainfall at planting time is highly variable, direct seeding may reduce the production risk (Singh *et al.,* 2006). Direct seeding can also reduce the hazard by avoiding terminal drought that lowers the yield of transplanted rice, mainly if the latter is recognized late due to delayed rainfall. Direct seeding can also facilitate crop intensification (Singh *et al.* 2008).

Seed rate has a great impact on plant density and the competitiveness of the crop stand, tillers, time to maturity and yield. Optimum planting density is the primary factor for obtaining higher yield in rice (Sivaesarajah *et al.* 1995). The number of plants/unit area has an impact on plant architecture, growth and development pattern and the production photosynthesis (Abuzar *et al.* 2011). Seeding rate is important traits for achieving higher seed yield in rice (Kurmi and Sarmah, 1993). Farmers are using 30–60 kg/ha for direct-seeded rice for inbred variety; however, with introduction of hybrids in direct-seeded rice, present quantity of seed rate seems to be higher on account of prices of hybrid seeds.

Application of inorganic fertilizers alone in large quantities over a longer period of time has resulted in imbalance in the supply of nutrients. The combined use of or-

[2]**Corresponding author's Email:** mksingh194.m@gmail.com

[1,3]Research Scholar, [2]Professor, [4]Assistant Professor, Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh 221 005

ganics and chemical fertilizers help in maintaining yield stability through correction of marginal deficiencies of secondary and micro-nutrients, enhancing efficiency of applied nutrients and providing favourable soil physical conditions (Pingali and Rosegrant, 1994). An INM approach is considered as most powerful tool for enhancing crop productivity and profitability for small and marginal farm holders. It becomes necessary and inevitable to utilize the INM technology coupled with direct-seeded rice (DSR) principles.

Vermicompost and FYM are good source of organic manure that can be used as an alternative to chemical fertilizers in rice cultivation (Prasad *et al.,* 2002). Choudhary and Suri (2014) reported that, FYM added good amounts of N, P and K in soil in addition to other macro and micronutrients essential for plant growth. Application of vermicompost increases total microbial population of N_2 fixing bacteria and actinomycetes (Tejada and Gonzalez, 2009). Jadhav *et al.* (2014) revealed, that recommended dose of nitrogen, phosphorus and potassium, i.e. 80–50–50 N–P and K kg/ha, and FYM with soil application of Fe and Zn resulted in significantly higher rice seed yield. Mohan *et al.* (2017) reported that application of 100% RDF + 2 foliar spray of 10 kg/ha $ZnSO_4$ + 5 kg/ha $FeSO_4$ + 10 kg Borax/ha + 10 kg/ha sulphur recorded increase in yield-attributing characters, viz. number of panicles, length of panicle, number of grains per panicle and test weight of rice which undoubtedly results in increase in yield of rice crop.

Micronutrients deficiency is a common nutritional problem in the rice–wheat cultivation. Crop production and quality is affected with deficient micronutrients (Fe, B and Zn) all over the world (Rashid and Ryan, 2004 and Rafique *et al.* 2008). Many studies have indicated that, micronutrients deficiency is a serious nutritional problem for upland crops. The foliar feeding of micronutrients is an effective method to yield improvement and grain nutrient enrichment (Johnson and Mortimer, 2005). Keeping these facts in view, the present study was undertaken to study effects of seed rate and integrated nutrient management on growth, yield parameters and net returns of direct-seeded hybrid rice.

MATERIALS AND METHODS

The field experiment was carried out during the rainy (*kharif*) seasons of 2016 and 2017 at the Agricultural Research Farm, Banaras Hindu University, Varanasi, (25º 18' N, 83º 03' E, 75.7 m above the mean sea-level) in the Northern Gangetic alluvial plains, Uttar Pradesh. The site was well-drained, sandy clay-loam soil, non-saline (EC 0.22 and 0.26 dS/m) with *p*H 7.52 (1 : 2.5 soil : water) and medium in organic carbon (0.42%), available P (22.85 kg/ha), available K (218.5 kg/ha) and low in available N (178.6 kg/ha) .

The experiment was laid out in a split-plot design with 3 replications. The seed rate was subjected to main plots while INM in subplots. A combination of 15 treatments, consisting of 3 seed rates, viz. S_1 (16 kg/ha), S_2 (20 kg/ha), S_3 (24 kg/ha), and 5 integrated nutrient-management treatments, viz. T_1, 100% recommended dose of fertilizer (RDF) through inorganic fertilizer; T_2, 100% RDF through inorganic fertilizer + $ZnSO_4$. $7H_2O$ 25 kg/ha followed by (*fb*) 0.2% $FeSO_4$ and 0.2% Borax foliar spray at 20 and 40 days after sowing (DAS); T_3, 75% recommended dose of nitrogen (RDN) through inorganic fertilizer + 25% N through FYM; T_4, 50% RDN through inorganic fertilizer + 50% N through FYM; and T_5, 75% RDN through inorganic fertilizer + 25% N through vermicompost. Dry-seeded hybrid rice cultivar 'ARIZE 6444' was sown on 29 June 2016 and 23 June 2017 during the first year and the second year respectively. The experimental field was ploughed with tractor-drawn plough followed by disking, dry weeds and stubbles were removed. Sowing was done manually with the help of *kudal* (local furrow maker) at a row spacing of 20 cm after putting fertilizers and covered with soil. Irrigation was done for proper germination after sowing the rice seeds. Recommended dose of fertilizer of nitrogen (140 kg/ha), P_2O_5 (60 kg/ha) and K_2O (60 kg/ha) were applied through urea (46% N), single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O). In T_3 and T_4 treatments, 25% and 50% N through FYM and in T_5 25% N through vermicompost was applied 15 days before sowing and required basal dose of nitrogen in T_3 (25% N) and T_5 (25% N) was applied through urea, respectively. Nitrogen 50% was applied at the time of sowing and rest nitrogen dose was applied in 2 equal splits at tillering and panicle initiation stages. In T_2 treatment, Zinc was applied in soil as basal dose whereas iron and boron were applied as foliar spray i.e. 0.2% $FeSO_4$ and 0.2% Borax applied at 20 and 40 DAS. Standard practices were followed to record biometrical observations and yield. Data were recorded on growth attributes, viz. plant height, tillers, leaf- area index, dry-matter accumulation, SPAD value, yield (grain and straw yields), harvest index, net returns and benefit–cost ratio. Available N, P, K and zinc were estimated after rice harvesting as per the standard soil analysis methodology.

RESULTS AND DISCUSSION

Growth attributes

At 60 DAS and at harvesting stage, seed rate of 20 kg/ha exhibited significantly better performance (Table 1) with respect to variation in tillers/m^2, dry-matter accumulation (g running/m) and leaf-area index than with 16 and

24 kg/ha. However, in case of plant height seed rate of 16 kg/ha resulted in the maximum plant height and it was found at par with 20 kg/ha. Growth attributes are important components, indicating performance of rice hybrids which might be owing to better phenotypic plasticity in reduced seed rate, i.e. 20 kg/ha. In recent past, reduced seed rate is being successfully used in rice crop production system like system of rice intensification for enhanced crop growth as reported by Pathania *et al.* (2016).

Amongst the integrated nutrient-management treatment, at 60 DAS and at harvesting stage; T_4 (50% RDN through inorganic fertilizer + 50% N through FYM) treatment recorded significantly higher plant height, number of tillers/m^2, dry-matter accumulation, leaf-area index and SPAD value than the rest of the INM treatments, except variations in plant height and LAI at 60 DAS which was found to be at par with T_3 (75% RDN through inorganic fertilizer + 25% N through FYM) . In case of variations in dry-matter accumulation, T_2 treatment [100% RDF + $ZnSO_4.7H_2O$ 25 kg/ha fb 0.2% ($FeSO_4$+ Borax) at 20 and 40 DAS] was at par with T_5 treatment (75% RDN through inorganic fertilizer + 25% N through vermicompost) at 60 DAS and at harvesting stages. At 60 DAS, tillers/m^2, leaf-area index and SPAD value; T_2 treatment [100% RDF + $ZnSO_4.7H_2O$ 25 kg/ha fb 0.2% ($FeSO_4$ + Borax) at 20 and 40 DAS] was at par with T_5 treatment (75% RDN through inorganic fertilizer + 25% N through vermicompost). The minimum value of growth parameters was observed in T_1 treatment (100% RDF through inorganic fertilizer). This might be owing to better availability of nutrients during all the crop growth stages which might have resulted in more nitrogen absorption by the roots for the synthesis of protoplasm responsible for rapid cell division consequently increasing plant shape and size. Our findings confirm the results of Ashwini *et al.* (2015).

Interaction effects on dry-matter accumulation and tillers/m²

At harvesting stage, interaction effect of INM and seed rate on dry-matter accumulation and tillers/m^2 was found significant (Table 2). Seed rate 20 kg/ha (S_2) in combination of 50% RDN through inorganic fertilizer + 50% N through FYM) (S_2T_4) resulted in the highest dry matter and tillers/m^2 and it was statistically at par with S_2T_3 treatment combination and significantly superior to rest of the treatment combinations. Higher dry-matter accumulation in seed rate (20 kg/ha) in combination with 50% RDN through inorganic fertilizer + 50% N through FYM might be due to uniform release and continuous availability of nutrients to the optimum seeding density. Our results confirm findings of Dutta and Chauhan (2010).

Yield

Rice sowing at 20 kg/ha resulted in significantly higher grain and straw yields than 16 and 24 kg/ha seed rate. The minimum grain and straw yields were recorded with seed

Table 1. Effect of seed rate and integrated nutrient management on growth attributes in direct-seeded hybrid rice (average data of 2 years)

Treatment	Plant height (cm)		Number of tillers/m^2		Dry-matter accumulation (g running/m)		Leaf-area index	SPAD value
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	60 DAS
Seed rate (*S*) (*kg/ha*)								
S_1, 16	72.04	107.93	383.99	365.59	53.18	190.99	3.90	39.86
S_2, 20	70.10	102.19	491.81	466.37	64.17	242.39	4.50	41.17
S_3, 24	62.82	93.58	453.37	422.17	59.55	221.16	4.24	37.98
SEm±	0.81	1.80	3.54	1.68	0.45	1.49	0.06	0.63
CD (P=0.05)	3.17	7.06	13.91	6.59	1.76	5.85	0.25	NS
Integrated nutrient management (T)								
T_1, 100% RDF	61.59	90.77	396.09	360.64	52.35	185.67	3.78	35.64
T_2, 100% RDF + $ZnSO_4.7H_2O$ 25 kg/ha fb 0.2% ($FeSO_4$+ Borax) at 20 and 40 DAS	67.84	100.38	430.56	410.79	58.02	210.56	4.16	39.60
T_3, 75% RDN + 25% N by FYM	72.16	106.27	472.77	453.98	62.37	239.96	4.46	41.89
T_4, 50% RDN + 50% N by FYM	74.14	110.11	493.07	465.29	65.85	248.42	4.65	43.15
T_5, 75% RDN + 25% N by vermicompost	65.89	98.64	422.79	399.53	56.23	206.29	4.02	38.07
SEm±	0.88	1.16	5.81	2.88	0.79	2.81	0.08	0.53
CD (P=0.05)	2.58	3.39	16.95	8.39	2.30	8.20	0.24	1.55

SPAD, Soil plant analysis development; RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; DAS, days after sowing; fb, followed by

rate of 16 kg/ha (Table 3). However, harvest index was not influenced by variable seed rate treatments during 2 years study. The grain yield of a crop is the integrated result of a number of physiological processes. The better performance of yield in 20 kg/ha seed rate might be owing to better performance of growth attributes owing to optimum seeding density. Hybrid rice cultivar shows phenotypic plasticity and because of optimum seeding density obtained in 20 kg/ha seed rate, fullest yield potential of hybrid cultivar might have been realized.

Amongst the various INM options, T_4 treatment (50% RDN through inorganic fertilizer + 50% N through FYM) resulted in significantly higher grain and straw yields. However, in the case of straw yield it was at par with T_3 treatment (75% RDN through inorganic fertilizer + 25% N through FYM). In case of grain and straw yields, T_2 treatment [100% RDF + $ZnSO_4.7H_2O$ 25 kg/ha fb 0.2% ($FeSO_4$ + Borax) at 20 and 40 DAS] was at par with T_5 (75% RDN through inorganic fertilizer + 25% N through vermicompost). This might be owing to increased growth attributes, viz. number of effective tillers, dry-matter accumulation (g running/m), leaf-area index and SPAD value, which finally transformed into higher yield. However, harvest index was not significantly influenced by INM treatments during both the years. Similar results were also recorded by Pandey *et al*. (2007), who observed that application of inorganic fertilizer @ 100–60–40 kg/ha N-P-K along with 10 tonnes farm yard manure (FYM) recorded

Table 2. Interaction effects of seed rate and integrated nutrient management on number of tillers/m^2 and dry-matter accumulation (g running/m) at harvesting in direct-seeded hybrid rice (average data of 2 years)

Integrated nutrient management (T)	Number of tillers/m^2			Dry-matter accumulation (g running/m)		
	Seed rate (S)			Seed rate (S)		
	S_1–16	S_2–20	S_3–24	S_1–16	S_2–20	S_3–24
T_1, 100% RDF	297.97	413.33	370.62	153.58	212.97	190.46
T_2, 100% RDF + $ZnSO_4.7H_2O$ 25 kg/ha fb 0.2% ($FeSO_4$+ Borax) at 20 and 40 DAS	378.58	441.63	412.15	195.11	228.68	207.89
T_3, 75% RDN + 25% N by FYM	384.61	517.69	459.65	207.31	265.35	247.22
T_4, 50% RDN + 50% N by FYM	396.17	528.98	470.72	209.18	278.96	257.12
T_5, 75% RDN + 25% N by vermicompost	370.64	430.22	397.72	189.78	225.99	203.10
	SEm±	*CD (P=0.05)*			*SEm*±	*CD (P=0.05)*
T at same levels of S	4.98	14.54			4.86	14.20
S at same or different levels of T	4.76	14.47			4.60	13.88

RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; DAS, days after sowing; fb, followed by

Table 3. Effect of seed rate and integrated nutrient management on yield, harvest index, Net returns, benefit: cost (B: C) ratio, organic carbon and available N, P, K and Zn (after rice harvesting during second year) in direct seeded hybrid rice (average data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Net returns (₹/ha)	Benefit: cost ratio	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Available Zn (mg/kg of soil)
Seed rate (*S*) (*kg/ha*)									
S_1, 16	4.91	6.89	41.02	52,189	1.17	204.7	21.7	215.5	1.15
S_2, 20	6.22	8.83	40.57	77,510	1.69	206.0	23.9	217.4	1.17
S_3, 24	5.64	8.06	40.53	64,733	1.37	203.1	22.0	214.9	1.13
SEm±	0.04	0.15	0.54	599	0.014	1.98	0.27	2.52	0.01
CD (P=0.05)	0.16	0.61	NS	2,352	0.06	NS	NS	NS	NS
Integrated nutrient management(T)									
T_1, 100% RDF	4.85	6.72	40.64	57,547	1.45	188.3	19.6	200.4	1.02
T_2, 100% RDF + $ZnSO_4.7H_2O$ 25 kg/ha fb 0.2% ($FeSO_4$ + Borax) at 20 and 40 DAS	5.46	7.62	40.83	67,199	1.58	204.4	21.6	214.6	1.21
T_3, 75% RDN + 25% N by FYM	5.99	8.68	40.24	76,510	1.71	212.0	23.4	223.2	1.10
T_4, 50% RDN + 50% N by FYM	6.28	9.11	40.37	78,427	1.60	222.4	23.9	230.4	1.16
T_5, 75% RDN + 25% N by vermicompost	5.37	7.50	41.44	44,371	0.70	196.3	21.3	210.9	1.05
SEm±	0.08	0.14	0.47	1,553	0.031	3.35	0.541	1.89	0.011
CD (P=0.05)	0.23	0.43	NS	4,534	0.09	9.79	1.58	5.36	0.03

the highest grain yield.

Interaction effects on grain yield

Interaction effects of seed rates and INM practices on grain yield was significant (Table 4). Seed rate 20 kg/ha and 50% RDN through inorganic fertilizer + 50% N through FYM (S_2T_4) resulted in the highest grain yield and it was superior to rest of the seed rate and INM combinations. Integrated sources of nutrients, i.e. fertilizers and farm yard manures, might have resulted in optimum availability essential minerals for crop plants in unit area obtained by seeding at 20 kg/ha and worked as catalyst for efficient use of applied nutrients for increasing the yield. Ramkrishna *et al.* (2007) also reported similar results.

Available nitrogen, phosphorus and potassium

Data pertaining to soil analysis, done after rice harvesting during the second year, revealed that seed rate treatment did not cause significant variations in available N, P, K and zinc in soil. All the nutrient-management treatments positively changed available N and K as compared to initial available soil nutrients. Amongst the INM treatments, T_4 treatment (50% RDN through inorganic fertilizer + 50% N through FYM) showed significantly higher available N and K than all the nutrient management treatments. T_3 treatment (75% RDN through inorganic fertilizer + 25% N through FYM) was found at par with T_2 treatment [100% RDF + $ZnSO_4.7H_2O$ 25 kg/ha fb 0.2% ($FeSO_4$ + Borax) at 20 and 40 DAS)] with respect to available N and it was significantly higher than T_2 in case of available P, K and Zn. Treatment T_2 [100% RDF + $ZnSO_4.7H_2O$ 25 kg/ha fb 0.2% ($FeSO_4$ + Borax) at 20 and 40 DAS] recorded higher available Zn than T_3 treatment (75% RDN through inorganic fertilizer + 25% N through FYM) and T_4 treatment (50% RDN through inorganic fertilizer + 50% N through FYM) treatments. This might be owing to higher availability of Zn because of application of zinc sulphate in T_2. Enhanced available pool of soil N with the application of fertilizers and organics after 2 years of experimentation might be owing to better decomposition and mineralization in the soil (Sharma and Subehia, 2014). The soils under inorganic fertilization exhibited reduction in available N and K as compared to integrated nutrient treatments. Higher available K under INM treatments than chemical fertilizers might be because of the addition of organic matter that reduced K-fixation and released K due to interaction of organic matter with clay, besides the direct K addition to the pools of soil (Urkurkar *et al*., 2010).

Economics

Economic analysis showed that seed rate of 20 kg/ha resulted in significantly higher net return and benefit–cost ratio than the other seed rate treatments. The minimum net return and benefit–cost ratio was recorded under 16 kg seed rate/ha (Table 3). This might be owing to more grain yield in 20 kg/ha seed rate treatments. These findings are in agreement with those of Mehala *et al.* (2016). Amongst various INM, T_4 treatment (50% RDN through inorganic fertilizer + 50% N through FYM) gave significantly higher net returns and it was at par with T_3 treatment (75% RDN through inorganic fertilizer + 25% N through FYM). Integrated nutrient management treatment T_3 (75% RDN through inorganic fertilizer + 25% N through FYM) showed significantly higher benefit–cost ratio than T_1, T_5 and T_4 (50% RDN through inorganic fertilizer + 50% N through FYM). This might be owing to better yield and reduced cost of cultivation in treatment T_3. Similar findings were also recorded by Pandey *et al*. (2007).

Interaction effects on net returns

Seed rate and INM practices had significant interaction effect on net return (Table 4). Combination of S_2T_4 (seed

Table 4. Interaction effects of seed rate and integrated nutrient management on grain yield in direct seeded hybrid rice (average data of 2 years)

Integrated nutrient management (T)	Grain yield (t/ha)			Net returns (₹/ha)		
	Seed rate (S)			Seed rate (S)		
	S_1–16	S_2–20	S_3–24	S_1–16	S_2–20	S_3–24
T_1, 100% RDF	4.0	5.5	4.9	43,059	71,439	58,144
T_2, 100% RDF + $ZnSO_4.7H_2O$ 25 kg/ha fb 0.2% ($FeSO_4$+ Borax) at 20 and 40 DAS	5.0	5.8	5.4	60,145	75,668	65,784
T_3, 75% RDN + 25% N by FYM	5.1	6.7	6.0	60,448	91,699	77,382
T_4, 50% RDN + 50% N by FYM	5.3	7.1	6.3	60,020	95,475	79,785
T_5, 75% RDN + 25% N by vermicompost	4.9	5.7	5.3	37,272	53,269	42,573
	SEm±	*CD (P=0.05)*			*SEm*±	*CD(P=0.05)*
T at same levels of S	0.13	0.40			2,690	7,854
S at same or different levels of T	0.13	0.39			2,480	7,371

RDF, recommended dose of fertilizer; RDN, recommended dose of nitrogen; DAS, days after sowing; fb, followed by

rate 20 kg/ha and 50% RDN through inorganic fertilizer + 50% N through FYM) showed the highest net returns and it was statistically at par with S_2T_3 treatment combinations and significantly superior to the rest of the seed rate and INM combinations.

It can be concluded that seed rate of 20 kg/ha along with 50% recommended dose of nitrogen through inorganic fertilizer + 50% N through FYM should be applied in direct-seeded hybrid rice for getting optimum yield under eastern Gangetic plains of Uttar Pradesh.

REFERENCES

Abuzar, M.R., Sadozai, G.U., Baloch, M.S., Shah, A.A., Javaid, T. and Hussain, N. 2011. Effect of plant population densities on yield of maize. *The Journal of Animal and Plant Sciences* **21**(4): 692–695.

Ashwini, M., Sridhar C.J., Saraswathi and Nethravathi, M.C.M. 2015. Effect of enriched FYM and fertilizer levels on growth and yield components of aerobic rice (*Oryza sativa*). *An International Quarterly Journal of Environmental Sciences* **8**: 153–159.

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

DES. 2015. *Agricultural Statistical at a Glance,* Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi.

DES. 2018. *Third Advance Estimates of Production of Food Grains for 2017–18,* Department of Agriculture, Cooperation and Farmers Welfare, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi.

Dutta, M. and Chauhan, B.S. 2010. Effect of nutrient management practice on the performance of upland rice in a newly developed terraced land. *Indian Agriculture* **54**(1/2): 13–21.

Gupta, R.K., Ladha, J.K., Singh, S, Singh, R.G., Jat, M.L., Saharawat, Y., Singh, V.P., Singh, S.S., Singh, G., Sah, G., Gathala, M., Sharma, R.K., Gill, M.S., Murshad, A., Hafiz, M.Ur.R., Singh, U.P., Mann, Pathak, R.A., Chauhan, H., Bhattacharya, B.S. and Malik, P.R.K. 2006. *Production Technology for Direct-Seeded Rice Rice–Wheat consortium for the Indo Gangetic Plains*, pp. 16. New Delhi.

IRRI. 2000. *Rice Production Training Module: Method of Planting Rice*. International Rice Research Institute, Los Barnos, Laguna, Philippines, pp. 1–13.

Jadhav, K.T., Lokhande, D.C. and Asewar, B.V. 2014. Effect of ferrous and zinc nutrient management practices on rice under aerobic condition. *Advances Research Journal of Improvement* **2**(5): 131–135.

Johnson, D.E. and Mortimer, A.M. 2005. Issues for weed management in direct-seeded rice and the development of decision-support frame works. (In:) *Workshop on Direct seeded Rice in the Rice–Wheat system of the Indo-Gangetic Plains,* 1–2 February 2005, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India, pp. 8.

Kurmi, K. and Sarmah, M.K. 1993. Effect of seed rate in nursery on transplanted rice. *Crop Research* **6**(1): 1–4.

Mehala, V., Sharma, U.K., Luhach, V.P. and Kumari, S. 2016. Impact of direct seeded rice on economics of paddy crop in Haryana. *International Journal of Agriculture Sciences* **8**(62): 3,525–3,528.

Mohan, A., Tiwari, A., Kumar, M., Pandey, D., Singh, A. and Singh, B. 2017. Effect of foliar spray of various nutrients on performance of rainfed rice (*Oryza sativa* L.). *Journal of Pharmacognosy and Phytochemistry* **6**(5): 2,252–2,256.

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

Pathania, R., Shekhar, J., Rana, S.S. and Sharma, S. 2016. Evaluation of seeding rates of rice nursery on seedling vigour and its effect on crop productivity under system of rice intensification. *Journal of Applied and Natural Science* **8**(4): 2,224–2,230.

Pingali, P.L. and Rosegrant, M.W. 1994. Confronting the environmental consequences of the green revolution. (In) *Proceedings of the 18th Session of the international Rice Commission*, Rome. Food and Agriculture Organization, Rome, Italy, pp. 59–69.

Prasad, P.V.V., Satyanarayana, V., Murthy, V.R.K. and Boote, K.J. 2002. Maximizing yields in rice–groundnut cropping sequence through integrated nutrient management. *Field Crops Research* **75**(1): 9–21.

Rafique, E., Mahmood-ul-hassan,M., Khokar, K.M., Nabi, G. and Tabassam, T. 2008. Zinc nutrition of onion: Proposed diagonistic criteria. *Journal of Plant Nutrition* **31**: 307–316.

Ramakrishna, Y., Subedar, S. and Parihar, S.S. 2007. Influence of irrigation regime and nitrogen management on productivity, nitrogen uptake and water use by rice (*Oryza sativa*). *Indian Journal of Agronomy* **52**(3): 102–106.

Rashid, A. and Ryan, J. 2004. Micronutrient constraint to crop production in soil with Mediterranen type characteristics: A review. *Journal of Plant Nutrition* **27**: 959–975.

Sharma, U. and Subehia, S.K. 2014. Effect of long term integrated nutrient management of rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) on productivity and soil properties inNorth-western Himalaya. *Journal of Indian Society of Soil Science* **62**(3): 248–254.

Singh S, Ladha, J.K., Gupta, R.K., Bhushan, L. and Rao, A.N. 2008. Weed management in aerobic rice systems under varying establishment methods. *Crop Protection* **27**: 660–669.

Singh, Y.P., Singh, G., Singh, S.P., Kumar, A., Sharma, G., Singh, M.K., Mortin, M. and Johnson, D.E. 2006. Effect of weed management and crop establishment methods on weed dynamics and grain yield of rice. *Indian Journal of Weed Science* **38**(1, 2): 20–24.

Sivaesarajah, K., Sangakkara, U.R. and Sandanam, S. 1995. Effect of plant density, nitrogen and gypsum on yield parameters of groundnut (*Arachis hypogaea* L.) in Regosols of Batticloa District. *Tropical Agricultural Research* **7**: 112–123.

Tejada, M. and Gonzalez, J.L. 2009. Application of two vermicompost on rice crop: effects on soil biological properties and rice quality and yield. *Agronomy Journal* **101**: 336–344.

Urkurkar, J.S., Tiwari, A., Shrikant, C. and Bajpai, R.K. 2010. Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Inceptisols. *Indian Journal of Agricultural Sciences* **80**(2): 208–212.