

## 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

K.S. SAINI<sup>1</sup>, JAGMOHAN KAUR<sup>2</sup>, THAKAR SINGH<sup>3</sup>, T.S. CHAHAL<sup>4</sup> AND S.S. MANHAS<sup>5</sup>

University Fruit Research Station, Punjab Agricultural University, Jallowal, Jalandhar, Punjab 144 303

Received: October 2019; Revised accepted: March 2020

### ABSTRACT

A field experiment was conducted on potato (*Solanum tuberosum* L.)-based cropping systems as an alternate to rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system at Jallowal (Jalandhar), Punjab, during 2016–17. Eight cropping systems, viz. potato–spring maize (*Zea mays* L.)–basmati rice, potato (*Solanum tuberosum* L.)–okra [*Abelmoschus esculentus* (L.) Moench]–basmati rice, potato–bottle gourd [*Lagenaria siceraria* (Molina) Standl.]–maize, potato–bitter gourd (*Momordica charantia* L.)–maize, potato–onion (*Allium cepa* L.)–maize, potato–summer greengram [*Vigna radiata* (L.) R. Wilezek]–maize, potato–summer greengram–basmati rice and rice–wheat, were laid out in randomized complete-block design with 3 replications. Rice-equivalent yield was higher in potato–onion–maize system (32.4 t/ha), being significantly higher than all the other systems. Potato–onion–maize system also resulted in the highest net returns of ₹293,000/ha followed by potato–bitter gourd–maize (₹260,000/ha) and potato–okra–basmati rice (₹249,000/ha) compared to rice–wheat systems (₹113,000/ha). The highest benefit: cost ratio of 1.32 was obtained in potato–onion–maize system. The production efficiency was also recorded higher in the same system. Both, energy-use efficiency and specific energy were the highest in rice–wheat system, which was statistically at par with potato–summer greengram–maize and potato–spring maize–basmati rice.

**Key words:** Benefit: cost ratio, Cropping systems, Energetics, Net returns

Rice–wheat is the most predominant cereal-based cropping system ensuring employment, food security, income and livelihood for millions of people (Singh *et al.*, 2014). It occupies 13.5 million ha area in the Indo-Gangetic plains (IGP) of South Asia (Gupta and Seth, 2007). Higher productivity, yield stability, mechanization, assured market price and less risk compared to other alternative cropping systems made this system more predominant one. Conventional transplanted rice, being a water-guzzler crop, is contributing for over-exploitation of the natural resource like water and environmental degradation through burning of crop residues. In contrary to this, being a cropping-intensive input-driven system and its adoption in non-traditional areas resulted in number of ecological, socio-economic and management problems.

In the present scenario of ever-increasing population, multiple cropping is one of the options to satisfy the increasing food demands and inclusion of high-value crops in crop sequences improves income of farmers (Bihari *et al.*, 2019). Potato being a high-value commercial crop and its large-scale utility in different products along with its nutritional superiority to most of the food crops makes it a good diversification option. Exceptionally high productivity of potato coupled with short-durability makes it compliant in intensive cropping systems. Accommodating maximum short duration crops in same piece of land in a year in the existing cropping system can help sustain food security along with better resource management. Summer greengram or moong has a lot of scope in crop diversification, as it fits well in different cropping systems owing to short duration and gives high yield. Inclusion of legumes in the cropping systems improves productivity and makes them more remunerative (Jacob *et al.*, 2016). Maize can play an important role in crop diversification, as it has great potential to be adjusted under diverse climatic conditions. Similarly, basmati rice fetches premium price in the market

<sup>1</sup>Corresponding author's Email: sainiks@pau.edu

<sup>1,3</sup>Senior Agronomist, <sup>2</sup>Assistant Agronomist, <sup>3</sup>Assistant Extension Specialist, Department of Agronomy, Punjab Agricultural University, Ludhiana; <sup>4</sup>Assistant Horticulturist, University Fruit Research Station, Jallowal, Punjab Agricultural University, Ludhiana, Punjab 141 004

because of its aroma and quality which adds to another diversified aspect for its adoption.

Under present scenario, energy is a critical aspect for national development and as cost of energy is rising day by day so it becomes immensely important to conserve energy. Rice has large amount of energy requirement as compared to other crops and different cropping systems vary in their energy-conversion efficiencies. Hence the present investigation was undertaken to evaluate diversification options in terms of productivity, profitability and energy use efficiency for replacing rice-wheat cropping system with different viable and sustainable potato-based cropping systems in potato belt of Doaba region of Punjab.

## MATERIALS AND METHODS

An experiment was conducted to study the feasibility of potato-based cropping systems as an alternate to rice-wheat at University Fruit Research Station, Punjab Agricultural University, Jallowal, Jalandhar (31°29'38" N and 75°37'40" E) in potato-dominated area during 2016–17. The soil of the experimental site was sandy loam, having pH 7.5, medium organic carbon (0.64), high available phosphorus (34.1 kg/ha) and medium available potassium (211 kg/ha). The experiment was laid out in a randomized complete block design with 3 replications. The treatments consisted of 8 cropping systems, viz., potato-spring maize-basmati rice; potato-okra-basmati rice; potato-bottle gourd-maize; potato-bitter gourd-maize; potato-onion-maize; potato-summer greengram-maize; potato-summer greengram-basmati rice and rice-wheat as a control. The cultivars, row spacing, seed rate, dates of sowing/transplanting and harvesting of crops and nutrients applied for different crops are given in Table 1. For comparison among different cropping systems, the yields of different crops were converted to rice-equivalent yield using the standard method. Production efficiency was worked out using the

method prescribed by Shukla *et al.* (2019). Apparent nutrient-use productivity was calculated as per Jacob *et al.* (2016) and apparent water productivity was calculated by the standard method.

The energy equivalents used in different cropping systems for various inputs and outputs were computed as suggested by Devasenapathy *et al.* (2009) and Rajanna *et al.* (2019). Net energy, energy-use efficiency, energy productivity (g/MJ) and specific energy were calculated as prescribed by Negi *et al.* (2016).

The data on different parameters were subjected to the analysis of variance (ANOVA) in randomized block design. The treatment means were compared by using critical difference ( $P=0.05$ ).

## RESULTS AND DISCUSSION

### Productivity of cropping systems

The rice-equivalent yield was the maximum in potato-onion-maize cropping system (32.4 t/ha) which was significantly higher than all the other cropping systems (Table 2). This increase over rice-wheat cropping system was 157% which might be attributed to the higher productivity of potato and onion in comparison to rice and wheat (Kachroo *et al.*, 2014). All the cropping systems resulted in significantly higher rice-equivalent yield than the most predominant rice-wheat cropping system. The rice-equivalent yield of potato-okra-basmati rice, potato-bitter gourd-maize, potato-bottle gourd-maize, potato-spring maize-basmati rice, potato-summer greengram-basmati rice and potato-summer greengram-maize was 134.1, 131.7, 124.6, 100.0, 74.6 and 71.4% higher than that of rice-wheat system. The inclusion of high-yielding vegetable crops of short-duration like potato, okra, bottle gourd, bitter gourd and onion in cereal-based cropping systems can provide good alternative to traditional rice-wheat cropping system for enhancing productivity. Gangwar and Singh (2011);

**Table 1.** Agronomic practices followed in different crops under potato-based cropping systems

Crop	Variety	Spacing (cm × cm)	Seed rate (kg/ha)	Date of sowing/ transplanting	Date of harvesting	Nutrients applied (kg/ha)			Market price (₹/q)
						N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	
Potato	'Kufri Pukhraj'	60×20	3,000	20-Oct.-2016	31-Jan.-2017	187.5	62.5	62.5	500
Wheat	'PBW 725'	20 (row-row)	100	25-Oct.-2016	10-Apr.-2017	125	62.5	-	1,625
Spring maize	'PMH 10'	60×20	25	31-Jan.-2017	2-Jun.-2017	125	60	-	1,450
Okra	'Punjab 8'	45×15	20	22-Mar.-2017	11-Jul.-2017	90	-	-	1,500
Bottle gourd	'Punjab Komal'	200×45-60	5	23-Feb.-2017	26-Jun.-2017	70	-	-	500
Bitter gourd	'Punjab 14'	150×45	5	23-Feb.-2017	26-Jun.-2017	100	50	50	1,500
Onion	'Punjab Naroya'	15×7.5	10	31-Jan.-2017	26-Jun.-2017	100	50	50	800
Summer greengram	'SML 832'	22.5×7	30	22-Mar.-2017	24-May-2017	12.5	40	-	4,250
Maize	'PMH 1'	60×20	20	26-Jun.-2017	30-Sep.-2017	125	60	30	1,450
Rice	'PR126'	20×15	20	26-Jun.-2017	30-Sep.-2017	125	30	30	1,590
Basmati rice	'Punjab Basmati 4'	20×15	20	11-Jul.-2017	8-Nov.-2017	40	-	-	3,825

and Mal *et al.* (2018) also reported enhanced system productivity with the inclusion of vegetables or legumes as compared to cereal-cereal cropping system. Among the different cropping systems, the production efficiency of potato–onion–maize was the highest and was significantly better than all the other cropping systems except potato–bitter gourd–maize, potato–okra–basmati rice and potato–bottle gourd–maize.

The highest apparent nutrient-use productivity was recorded in potato–okra–basmati rice system and was significantly higher than the remaining cropping systems. This is owing to the fact that the nutrient requirement of both okra and basmati is less than all the other crops. Significantly higher apparent nutrient -use productivity was obtained in all the cropping systems as compared to the rice–wheat system except potato–summer greengram–maize which was statistically similar to that system. This is owing to the higher rice-equivalent yield obtained in all the systems although the nutrient requirement of these systems involving 3 crops is higher than rice–wheat system. Among the potato-based cropping systems, the least value of apparent nutrient-use productivity was obtained in potato–summer greengram–maize system, which might be due to more

nutrient-exhaustive potato and maize crops. Although nutrient requirement of greengram is low, less yield of this pulse crop as compared to vegetables reduces system rice-equivalent yield, resulting in lesser nutrient-use productivity. Apparent water productivity was the highest in potato–bitter gourd–maize and was statistically at par with potato–onion–maize, potato–bottle gourd–maize, potato–summer greengram–maize and significantly better than potato–okra/spring maize/summer greengram–basmati rice and rice–wheat cropping systems. Owing to the water-intensive nature of the rice crop, it increases the irrigation requirement of the system, thus reduces the apparent water productivity of the cropping system.

### Economics

The highest gross returns were obtained in potato–onion–maize, followed by potato–okra–basmati rice, potato–bitter gourd–maize, potato–bottle gourd–maize, potato–spring maize–basmati rice, potato–summer greengram–basmati rice and potato–summer greengram–maize and the least was obtained in rice–wheat system (Table 3). Potato–onion–maize also gave the highest net returns of ₹293,000/ha, followed by potato–bitter gourd–maize

**Table 2.** Yield of different crops, rice-equivalent yield (REY), production efficiency, apparent nutrient-use productivity and apparent water productivity of potato-based cropping systems

Treatment	Winter crop yield (t/ha)	Spring crop yield (t/ha)	Rainy season crop yield (t/ha)	REY (t/ha)	Duration (days)	Production efficiency (kg/ha/day)	Nutrient-use productivity (kg/ha/kg nutrient applied)	Apparent water productivity (kg/m <sup>3</sup> )
Potato–spring maize–basmati rice	35.7	7.88	2.83	25.2	345	73.10	46.9	1.20
Potato–okra–basmati rice	35.9	12.0	2.86	29.5	334	88.29	66.6	1.49
Potato–bottle gourd–maize	35.5	34.4	6.98	28.3	322	87.98	47.4	2.15
Potato–bitter gourd–maize	34.5	12.8	6.86	29.2	322	90.66	40.1	2.21
Potato–onion–maize	35.1	29.6	7.08	32.4	345	93.92	44.5	2.16
Potato–summer greengram–maize	35.3	1.45	7.29	21.6	262	82.55	37.3	2.12
Potato–summer greengram–basmati rice	35.1	1.41	2.98	22.0	286	76.79	54.2	1.36
Wheat–rice	5.62	–	6.84	12.6	263	47.85	33.8	0.70
SEm±	–	–	–	0.96	–	3.06	1.95	0.06
CD (P=0.05)	–	–	–	2.9	–	9.29	5.9	0.19

**Table 3.** Gross, net returns and benefit: cost ratio of potato-based cropping systems

Treatment	Gross returns (‘000₹/ha)	Net returns (‘000₹/ha)	Benefit: cost ratio
Potato–spring maize–basmati rice	401.0	198.5	0.98
Potato–okra–basmati rice	468.9	249.0	1.13
Potato–bottle gourd–maize	450.4	237.0	1.11
Potato–bitter gourd–maize	464.1	260.0	1.27
Potato–onion–maize	515.2	293.0	1.32
Potato–summer greengram–maize	343.9	168.4	0.96
Potato–summer greengram–basmati rice	349.2	165.1	0.90
Wheat–rice	200.1	113.0	1.30

(₹260,000/ha), potato-okra-basmati rice (₹249,000/ha) as compared to predominant cereal-based rice-wheat system (₹113,000/ha). The highest B: C ratio was obtained in potato-onion-maize followed by rice-wheat system. Other vegetable-and cereal-based cropping systems had lower B: C ratio than the predominant cereal-based rice-wheat system which might be due to more cost of cultivation and also lower market price of different crops.

### Energetics

Among all the cropping systems, the highest input energy was used in potato-onion-maize ( $86.09 \times 10^3$  MJ/ha) and the least was required in rice-wheat ( $43.40 \times 10^3$  MJ/ha) system (Table 4). The cropping systems involving 3 crops required higher energy input than the cropping systems with 2 crops. The higher input requirement in potato-based cropping system might be because of more input requirement like seed, FYM, fertilizers, herbicides and labour. Onion crop needs transplanting of seedlings and also manual weedings, thus it is also very labour-intensive and thus potato-onion-maize system involves high energy values. The second highest input was recorded in potato-bitter gourd-maize ( $80.91 \times 10^3$  MJ/ha). The highest share in energy inputs in different cropping systems was mainly contributed by fertilizers (24.7 to 38.14%), followed by

seed (4.06 to 24.14%), organic manures (18.8 to 26.97%) and irrigations (8.89 to 26.13%). The least was contributed by pesticides (0.58 to 1.79%), followed by herbicides (1.10 to 2.52%), labour (2.05 to 6.32%) and tractor (4.48 to 5.58%).

Total energy output was computed from main product and by-product of different cropping systems and it ranged from 407.62 to  $678.60 \times 10^3$  MJ/ha (Table 5). Significantly higher energy output was obtained from potato-spring maize-basmati rice followed by potato-summer greengram-maize, potato-onion-maize and potato-bottle gourd-maize systems, thus these systems proved to be efficient energy converters although their energy-input requirement was more than traditional rice-wheat. The net energy output also followed the similar trend. The least net energy output was obtained from potato-okra-basmati rice ( $333.43 \times 10^3$  MJ/ha).

Energy-use efficiency was the highest in rice-wheat (9.39), being statistically at par with potato-summer greengram-maize (9.06) and potato-spring maize-basmati rice (8.51) cropping systems. Highest energy productivity was recorded in potato-okra-basmati rice and was statistically at par with potato-onion-maize and potato-bitter gourd/bottle gourd-maize cropping systems, which might be because of better utilization of available resources and

**Table 4.** Energy values ( $\times 10^3$  MJ/ha) of various inputs in potato-based cropping systems

Treatment	Seed	Farmyard manure	Fertilizers	Herbicides	Pesticides	Labour	Tractor	Irrigations	Total
Potato-spring maize-basmati rice	15.96	15.0	25.43	1.79	1.09	3.55	3.73	13.23	79.78
Potato-okra-basmati rice	15.89	15.0	21.27	1.90	1.12	3.80	4.05	12.47	75.51
Potato-bottle gourd-maize	15.67	19.5	25.85	0.89	0.60	3.23	4.37	8.32	78.43
Potato-bitter gourd-maize	15.67	19.5	28.32	0.89	0.60	3.23	4.37	8.32	80.91
Potato-onion-maize	15.74	19.5	28.46	1.49	0.50	5.44	4.37	10.58	86.09
Potato-summer greengram-maize	16.15	19.5	22.47	1.25	0.55	2.73	3.24	6.43	72.31
Potato-summer greengram-basmati rice	16.15	15.0	16.52	1.67	1.04	3.05	3.24	10.21	66.88
Wheat-rice	1.76	9.0	16.56	0.81	0.78	0.89	2.27	11.34	43.40

**Table 5.** Energetics of potato-based cropping systems

Treatment	Energy output ( $\times 10^3$ MJ/ha)	Net energy output ( $\times 10^3$ MJ/ha)	Energy use efficiency	Energy productivity (kg/MJ)	Specific energy (MJ/kg)
Potato-spring maize-basmati rice	678.6	598.8	8.51	0.32	3.17
Potato-okra-basmati rice	408.9	333.4	5.42	0.39	2.57
Potato-bottle gourd-maize	629.7	551.2	8.03	0.36	2.77
Potato-bitter gourd-maize	557.6	476.7	6.89	0.36	2.77
Potato-onion-maize	640.3	554.2	7.44	0.38	2.66
Potato-summer greengram-maize	655.4	583.1	9.06	0.30	3.36
Potato-summer greengram-basmati rice	410.0	343.1	6.13	0.33	3.06
Wheat-rice	407.6	364.2	9.39	0.29	3.45
SEM $\pm$	24.39	24.39	0.32	0.013	0.11
CD (P=0.05)	73.98	73.98	0.98	0.039	0.32

the maximum system productivity. Patra *et al.* (2019) also found increase in the energy productivity with the inclusion of maize and vegetables. Specific energy was the highest in rice–wheat (3.45 MJ/kg), statistically at par with potato–summer moong–maize cropping system (3.36 MJ/kg) and potato–spring maize–basmati rice (3.17) and significantly better than the alternative cropping systems. This indicated that these cropping systems require higher inputs to produce a unit of produce. The least specific energy was obtained in potato–okra– basmati rice which was to the tune of 2.57 MJ/kg. Thus, inclusion of vegetables in cereal-based cropping systems resulted in low input use per kg of the produce.

Based on the above findings, it can be concluded that potato–onion–maize system is the most productive and remunerative system for diversifying traditional rice–wheat, followed by potato–bitter gourd–maize and potato–lady finger–basmati rice. All these systems also resulted in higher energy productivity. Potato–bitter gourd–maize had the highest apparent water productivity, whereas potato–okra–basmati rice had the highest apparent nutrient-use productivity. Adoption of these viable diversification options available for the farmers can help to realize higher productivity, profitability and resource-use efficiency.

## REFERENCES

- Bihari, B., Singh, M., Bishnoi, R. and Mishra, P.K. 2019. Issues, challenges and strategies for doubling farmer's, income in India–A Review. *Indian Journal of Agricultural Sciences* **89**(8): 1,219–1,224.
- Devasenapathy, P., Senthil Kumar, G. and Shanmugam, P.M. 2009. Energy management in crop production. *Indian Journal of Agronomy* **54**(1): 80–89.
- Gangwar, B. and Singh, A.K. 2011. *Efficient Alternative Cropping Systems*, pp. 186. Project Directorate for Farming Systems Research, Modipuram, Meerut, Uttar Pradesh, India.
- Gupta, R. and Seth, A. 2007. A review of resource conserving technologies for sustainable management of the rice–wheat cropping systems of the Indo-Gangetic Plains (IGP). *Crop Protection* **26**(3): 436–447.
- Jacob, D., Mathew, T., Jacob, J., Rani, B. and Sukumari, P. 2016. On-farm farmers' participatory evaluation of intensification of rice (*Oryza sativa*)–rice–fallow system with vegetables in summer under humid tropical irrigated lowlands. *Indian Journal of Agronomy* **61**(3): 281–285.
- Kachroo, D., Thakur, N.P., Kaur, M., Kumar, P., Sharma, R. and Khajuria, V. 2014. Diversification of rice (*Oryza sativa*)-based cropping system for enhancing productivity and employment. *Indian Journal of Agronomy* **59**(2): 21–25.
- Mal, T., Walia, S.S. and Saini, K.S. 2018. Productivity and economics of different cropping systems in relation to tillage, mulching and fertilizer management practices in north-western Indo-Gangetic Plains of India. *Indian Journal of Agricultural Sciences* **88**(2): 216–221.
- Negi, S.C., Rana, S.S., Kumar, A., Subehia, S.K. and Sharma, S.K. 2016. Productivity and energy- efficiency indices of diversified maize (*Zea mays*)-based cropping systems for mid hills of Himachal Pradesh. *Indian Journal of Agronomy* **61**(1): 9–14.
- Patra, A. K., Garnayak, L.M., Mishra, K.N., Paikaray R.K. and Bastia, D.K. 2019. Productivity, resource-use efficiency and economics of rice (*Oryza sativa*)-based bio-intensive cropping systems in coastal Odisha. *Indian Journal of Agronomy* **64** (2): 165–171.
- Rajanna, G.A., Dhindwal, A.S., Rawal, S. and Pooniya, V. 2019. Energetics, water and crop productivity of wheat–clusterbean sequence under land configuration and irrigation regime in semi-arid agro-eco system. *Indian Journal of Agronomy* **64**(4): 450–457.
- Shukla, D.K., Singh, V.K., Bhushan, C. and Kumar, A. 2019. Influence of phosphorus fertilization on productivity and biological sustainability of chickpea (*Cicer arietinum*) + coriander (*Coriandrum sativum*) intercropping system. *Indian Journal of Agronomy* **64** (3): 315–319.
- Singh, S.S., Singh, A.K. and Sundaram, P.K. 2014. Agrotechnological options for upscaling agricultural productivity in eastern Indo-Gangetic Plains under impending climate change situations: A review. *Journal of AgriSearch* **1**(2): 55–65.



## REVISED GUIDELINES FOR CONTRIBUTORS

*Indian Journal of Agronomy* (IJA) is a quarterly publication (March, June, September, and December) of the Indian Society of Agronomy. It is being published regularly since the establishment of the Society in 1955. It enjoys a NAAS rating of 5.46 out of 10. The detailed guidelines (available on our Society website [www.isa-india.in](http://www.isa-india.in)) for the preparation of articles by the authors are given below.

### 1. AIMS AND SCOPE

- 1.1 *Indian Journal of Agronomy* welcomes concise articles presenting original research results based on field experiments on all aspects of Agronomy in various crops and related cropping systems.
- 1.2 The Journal publishes full-length comprehensive articles based on new approaches/findings in English. Short Communications, based M.Sc. Agronomy thesis results are also considered.
- 1.3 Review articles are also published, but these are specifically solicited by the Editorial Board. However, authors wishing to contribute a review article on their own, based on their standing in the relevant field, and may contact the Secretary of the Indian Society of Agronomy or the Chief Editor with a broad outline before submitting the manuscript. Manuscripts submitted without following the above procedure will be rejected.
- 1.4 The articles submitted for publication in the Journal should contain data not older than 5 years on the date of their receipt in the Society office. The period shall be reckoned from the following 31 December and 31 July after the completion of the field experimentation for summer (*Zaid*) and rainy (*Kharif*), and winter (*Rabi*) and spring seasons, respectively.
- 1.5 The articles submitted for publication should be exclusive for this Journal and must not have been submitted elsewhere. They must not include any material that has already been published in the same or different forms.
- 1.6 The article should present a complete picture of the investigation made and should not be split into parts. However, in exceptional cases, where a large volume of in-depth data has been collected, based on multi-season/location experimentation, the article can be split into two parts, with the same main title and a different short sub-title. In such articles, proper continuity should be maintained in the presentation of information, and all the parts should be submitted together.
- 1.7 Each article should be written in English clearly, objectively, and concisely. All the statements should be clear, unambiguous, and to the point. One should aim at short meaningful sentences while maintaining continuity of expression.
- 1.8 There is no prescribed upper limit regarding the number of pages in case of a full-length article; what is important is that it contains complete information. However, the length of the article should not be less than 3 full printed pages of the Journal.
- 1.9 Articles should be suitably divided into the following sub-sections: TITLE, AFFILIATION, ABSTRACT, KEYWORDS, INTRODUCTION, MATERIALS AND METHODS, RESULTS AND DISCUSSION, CONCLUSION, and REFERENCES. Tables and figures should be appended at the end of the text. The headings INTRODUCTION and CONCLUSION need not be mentioned in the text.
- 1.10 Research articles will be published only when they are based on data for a minimum of 2 years. Further, if the experiments were conducted on the same site and the results were similar in the two years of study, it is suggested that data be pooled over 2 years to save time to the reader and space in the Journal. Also, it will be easier to discuss the results. Articles reporting pooled data and only a few tables will be given priority for publication. For experiments conducted over a period of more than 2 years, year-wise data may be given only when the results are variable from year to year and there is a good discussion of the reasons causing these variations. Short notes based on one-year results (M.Sc. Thesis) will also be accepted, provide they do not contain more than two short tables and the entire manuscript does not exceed 6 pages (typed double space, including tables). Short notes will have TITLE AFFILIATION, ABSTRACT, and KEYWORDS but no subheadings in the subsequent text.

### 2. TITLE PAGE

- 2.1 Title of the article should be concise and informative, and should not contain abbreviations. It should reflect the content of the article to facilitate keyword indexing and information retrieval. A good title briefly identifies the subject, indicates the purpose of the study, and introduces key terms and concepts. It should be set in lower case and bold

letters, using one font size higher than the remaining text (Times New Roman, 12 Font, double space). Use of words such as 'Effect/Impact of ....' Or 'Influence of ....' in the title should be avoided.

- 2.2 Wherever relevant, the title should indicate the scientific name of the crops or organisms studied without mentioning the authority. Authority should be given at the first mention of the name in the subsequent text.
- 2.3 A short title, not exceeding 6 words or 50 characters, should also be given for running headlines. This should cover the main theme of the article.
- 2.4 Byline should contain, in addition to the names and initials of authors (in capital letters), the place (in italics) where the research was conducted and not where the authors are currently working. Change of address for any author should be given as a footnote. A complete address including the name of the laboratory/department, institution/university, city town/district, state, and PIN code should be furnished.
- 2.5 Email ID of the corresponding author should be given as a footnote. It will facilitate correspondence and quick processing of articles.

### 3. ABSTRACT

- 3.1 Second page should start again with the title of the article and then be followed by the abstract. The abstract should briefly (not exceeding 250 words) present the factual summary of salient points of the contents including objectives (not the wording of the title as such), season or year and the place of study as appropriate, materials and methods, main results (preferably including some numerical values) and important conclusion/recommendation and should refer to any new information therein.
- 3.2 The complete scientific name (including authority) for plants and other organisms, and the full name of any abbreviation or symbol used should be given at their first mention.
- 3.3 Reference to literature and tables/figures and use of such expressions as 'will be discussed' or 'will be explained' should be avoided.
- 3.4 Keywords (6-8) should be given at the end of the abstract in alphabetical order (each keyword to start with a capital letter), separated by a comma. These words should indicate the most important materials, operations, or ideas covered in the article.
- 3.5 Indexing journals place a great emphasis on the quality of the abstract in the selection of articles for abstracting. If properly prepared, they reproduce

it verbatim. Hence, due attention should be paid in preparing the abstract.

### 4. INTRODUCTION

- 4.1 The word 'Introduction' should not be typed as a heading but the beginning of the main text should be side marketed by putting a one cm long line below the abstract in the middle.
- 4.2 It should be brief and to the point, well define the problem that justifies the work or of the hypothesis on which it is based, and an explanation of the general approach and objectives of the study.
- 4.3 It should set the work in the present context, giving only essential background; a detailed review of literature is not necessary. However, to orient the readers, a brief reference to previous concepts and research should be made.
- 4.4 It should briefly state the currently available information on the subject, duly supported by recent and relevant literature, and identify the research gap that is expected to be bridged through the investigation being reported in the article.
- 4.5 When new references are available, the use of old references should be avoided unless they are of historical importance or a landmark in that field.
- 4.6 Emphasis should be given among other things on citing the literature on work done under Indian conditions and published in the previous volumes of Indian Journal of Agronomy.
- 4.7 If the methods employed in the article are new, this must be indicated.

### 5. MATERIALS AND METHODS

- 5.1 This part of the article should comprise the materials used in the investigation, and the methods of experimentation and analysis adopted. It should have all the requisite information for providing a clear understanding and assessment of the results reported subsequently. It should begin with information relating to period/season/year and place of study, climate or weather conditions, soil type including physicochemical properties, and others as relevant to the study. While giving values for available nutrients, the method used and reference to the practical manual or book, where the method is described should be given.
- 5.2 The geographical position of the experimental site should be identified with the help of coordinates (latitude and longitude) and altitude. Presentation of the study site map is welcome.
- 5.3 Treatment details along with techniques and experimental design, replications, plot size, etc.

should be clearly indicated. The experimental design adopted should have ensured that appropriate error degrees of freedom are there. The pooling of data should be done only when year x treatment interaction effects are not significant. The pooling of data must be avoided in dryland; rainfed experiments and fixed site experiments for the entire period of experimentation. If asked, the authors must be able to give the homogeneity of error variance.

- 5.4 Use of symbols for treatments may be avoided unless these are absolutely necessary. An abbreviation should be fully explained when first mentioned.
- 5.5 Details such as the crop variety (within single inverted commas), the methodology for application of treatments, common cultivation practices including sowing, fertilization, weed management, irrigation, plant protection measures, harvest, etc should be given. For cropping system experiments, it should be clearly stated as to whether the study was carried out on a fixed location for the entire experimental period or the location changed every year. In rainfed and dryland experiments, initial moisture status at sowing (and if possible, at different stages), rainfall distribution, and evaporation (as a graph) should be given. If the treatments are based on moisture conservation practices (summer ploughing, manures, mulching, land configuration, etc.), moisture conserved, extraction, and utilization data must be given. In irrigation studies (based IW/CPE ratio), daily evaporation and rainfall data in the form of a graph along with the dates of irrigation mentioned year-wise in the text are necessary. The nutrient composition of manures (N, P, K, Fe, Zn, organic carbon content, etc.) should be given. For new herbicides, the mode of action should be stated.
- 5.6 A brief description of the specific observations recorded should be made. Further, the procedure for calculation of any new parameters reported should be explained along with suitable references.
- 5.7 Methods of analysis commonly used need not be described in detail. However, any new technique developed and followed should be described.
- 5.8 References for methods used in the study should be cited. If the techniques used are widely known (such as those of chemical and statistical analysis), only their names should be indicated.
- 5.9 All statistical comparisons among treatments may be made at the  $P=0.05$  level of probability. Correlation and regression analysis should be given

when necessary. For working out optimum economic doses, the experiment should include a control treatment.

## 6. RESULTS AND DISCUSSION

- 6.1 Results may be reported and discussed together to avoid duplication. The information should be divided into suitable sub-headings, typed in italics.
- 6.2 The section should not be a mere repetition of the data presented in the tables and diagrams. Instead, there should be an effort to interpret them suitably by indicating changes or any other derivations. In the factorial experiments, emphasis should be laid on explaining interactions.
- 6.3 While discussing the results, particular attention should be given to the problem, question, or hypothesis presented in the introduction. Results should be related to the objectives. Parameters that are of little consequence for the overall objective of the study should not be described/discussed
- 6.4 Any principles, relationships, and generalizations that can be supported by the results should be elaborated.
- 6.5 Discussion should be strengthened by explaining treatment effects in terms of cause and effect relationship. Explain how the results relate to previous findings (support, contradict).
- 6.6 Scientific speculation is encouraged, but it should be reasonable and firmly founded in observations. When the results differ from previously available information, possible explanations should be given. Controversial issues should be discussed clearly and fairly.
- 6.7 The references quoted in the introduction for review and justification of the study should be suitably utilized for discussion of the results.
- 6.8 Statement like “The results are in agreement with .....”, ‘Similar results were reported by .....’ should normally be avoided.
- 6.9 Avoid sentences with ‘respectively’. For example “On average, organic manure treatment resulted in the reduction in yields of wheat, potato and vegetable pea by 16.0, 16.8 and 12.5%, respectively, than the fertilizer application treatment.” It should better be written, “As compared to chemical fertilizer, organic manure application lowered the yield of wheat by 16.0%, of potato by 16.8% and of vegetable pea by 12.5%.”

## 7. CONCLUSION

- 7.1 The word ‘Conclusion’ need not be typed as a heading and may be given as a last paragraph of

the 'Results and Discussion'. In no case, it should exceed more than 5 sentences.

- 7.2 The section should clearly crystallize the summary of the results obtained along with their implications in the solution of the practical problems and contribute to the advancement of scientific knowledge.
- 7.3 It should suggest areas for further investigation.

## 8. ACKNOWLEDGEMENT

The authors may place on record the help and co-operation received from any source, person, or organization for this study if they feel it necessary. It should be very brief. Routine acknowledgments to the heads of departments, institutes, or organizations for providing facilities to conduct the study should be avoided, as it is their duty to do so.

## 9. REFERENCES

- 9.1 In general, not more than 10 references be included in the research articles. The references, in general, must not be older than 10 years. Only in exceptional cases (e.g. in case of a landmark work or where no suitable recent references are available) should the older work be referred to.
- 9.2 There is no need to give references for standard procedures of soil and plant analysis, as well as for routine statistical analysis.
- 9.3 All references cited in the text must appear at the end of the article and *vice-versa*. The spellings of names and dates or years at the two places should be carefully checked.
- 9.4 The references should include names of all authors, year (not within brackets), the full title of the article, full name of the journal (*in italics*) (no abbreviations), volume number (in bold), issue number (in the bracket, not bold), and pages. For book or monograph, the name of the publisher should also be given as well as its volume, edition and relevant page range. The examples are given below.
- 9.5 The references cited together in the text should be arranged chronologically. The list of references should be arranged alphabetically on the author's names, and chronologically per author.
- 9.6 References from previous volumes of Indian Journal of Agronomy and other standard scientific journals should be preferred, while those concerning unpublished data are generally avoided or mentioned as 'Personal communications' in the text. These need not be given in the reference list. A few examples for correct citation of references are

given below:

### 9.6.1 Research articles

- Bisht, J.K. 2009. Effect of different cropping sequences and fertility levels on the winter dual-purpose food and fodder crops. *Archives of Agronomy and Soil Science* **55**(5): 515–524
- Saha, R. and Ghosh, P.K. 2010. Effect of land configuration on water economy, crop yield, and profitability under rice (*Oryza sativa*)-based cropping systems in northeast India. *Indian Journal of Agricultural Sciences* **80**(1): 16–20
- Sharma, B.R., Rao, K.V., Vittal, K.P.R., Ramakrishna, Y.S., and Amarasinghe, U. 2010. Estimating the potential of rainfed agriculture in India: Prospects for water productivity improvements. *Agricultural Water Management* **97**(1): 23–30

### 9.6.2 Book

Bandyopadhyay, P.C. (Ed.) 2010. *Fertigation: Fundamentals and Applications*. 336 p. Daya Publishing House, Delhi, India.

### 9.6.3 Book Chapter

Ali, M., Singh, K.K., Pramanik, S.C., and Omar Ali, M. 2009. Cropping systems and production agronomy. In: *The Lentil: Botany, Production, and Uses*. (Erskine, W., Muehlbauer, F., Sarker, A. and Sharma, B. Eds.). pp. 213–228. CABI, Wallingford, UK.

### 9.6.4 Annual Report

IARI. 2008. Organic farming of rice-based cropping systems with respect to nutrient management. *Annual Report 2008-09*. Indian Agricultural Research Institute, New Delhi. p. 48.

### 9.6.5 Proceedings

Schlestinger, W.H. 2009. On the fate of anthropogenic nitrogen. In: *Proceedings of the National Academy of Sciences, USA* **106**(1): 203–208.

### 9.6.6 Abstracts

Vairavan, K. 2009. Effect of pre and post emergence herbicide in pigeonpea. In: *Abstracts, International Conference on Grain Legumes: Quality Improvement, Value Addition and Trade*, 14–16 February, 2009, Indian Society of Pulses Research Development, Indian Institute of Pulses Research Kanpur, India. p. 178.

### 9.6.7 Extended Summaries

Srinivasarao, Ch., Venkateswarlu, B., Vittal, K.P.R.,

Kundu, S. and Gangaiah, B. 2010. Carbon stocks in different soil types in relation to rainfed production system and climate in tropical India. In: *Extended Summaries, National Symposium on Climate Change and Rainfed Agriculture*, 18–20 February, 2010, Indian Society of Dryland Agriculture, CRIDA. Hyderabad, India. pp. 272–274.

#### 9.6.8 *Technical Report/Bulletins*

NNRMS. 2008. Space technology application for climate change. *Technical Report ISRO/ DOS/TR/ 01/2008*. 50 p.

#### 9.6.9 *Online publications*

EPA. 2008. In: Carbon sequestration in Agriculture and Forestry. ([www.cpa.gov/ sequestrations/ index.html](http://www.cpa.gov/ sequestrations/ index.html)).

#### 9.6.10 *Thesis*

Ram Swaroop Bana. 2009. Effect of preceding summer forage crops and phosphogypsum enriched urea on the productivity and quality of aromatic rice. *Ph. D. Thesis*, Division of Agronomy, Indian Agricultural Research institute, New Delhi, India. Pp. 154.

### 10. TABLES

- 10.1 Each table must be typed on a separate sheet (not to be included in the text) and numbered consecutively in the same order as they are mentioned in text.
- 10.2 The title should fully describe the contents of the table and explain any symbol or abbreviation used in it as a footnote, using asterisks or small letters, viz. a, b, etc.
- 10.3 Tables should be self-explanatory, not very large (< 10 columns in portrait and < 14 columns in landscape formats respectively) and may cover space up to 20-25% of the text.
- 10.4 Maximum size of table acceptable is what can be conveniently composed within one full printed page of the journal. The large sized tables should be suitably split into two or more small tables.
- 10.5 Standard abbreviations of units of different parameters should be indicated between parentheses.
- 10.6 The data in the tables should be corrected to minimum place of decimal, so as to make it more meaningful.
- 10.7 Vertical lines should not be used to separate

columns. Similarly, horizontal lines should be used only where these are necessary, not in the body of the table.

- 10.8 All the tables should be placed after references.

### 11. FIGURES

- 11.1 Figures may be given in place of tables where a large number of values are presented that can be interpreted through figures. In no case, the same data should be presented in both tables and figures. The inclusion of CD values in figures will help to make the figure more comprehensive.
- 11.2 Original figures should not be larger than twice the final size. They should be of good quality and printed clearly in black on plain white paper (not in colour). The figures may be sized to fit within the columns of the journal (8 cm width for a single column or 17 cm for the full page).
- 11.3 Lines should be bold enough to allow the figure to be reduced to either single or double column width in the journal.
- 11.4 Vertical axes should be labeled vertically. Extremely small font and great variation in text sizes within figures should be avoided. The aim should be that on printing the words and figures, including the caption, come to 9 pt type size.
- 11.5 Laser print outs of line diagrams are acceptable, while dot-matrix printouts will be rejected. If required, the authors will be asked to submit a soft copy of the diagrams of accepted articles for final print in the Journal.
- 11.6 Illustrations can also be traced on a white art card, using the proper stencil. The numbers and letterings must be stencilled; free-hand drawing will not be accepted.
- 11.7 Colour photographs are accepted if these are necessary to improve the presentation and quality of the article.

### 12. SOME USEFUL HINTS

- 12.1 All scientific or technical names as well as all data and facts must be rechecked carefully before submitting the manuscript.
- 12.2 Dates and years may be mentioned as 28 May 2007, 28 May to 7 June, and 28-30 May instead of May 28, 2007, 28 May-7 June, and 28 to 30 May, respectively.
- 12.3 Avoid numerals and abbreviations at the beginning of a sentence; spell out or change the word order if necessary.
- 12.4 A comma may be used for data in thousands or more

- such as 10,000 or 2, 30,000 etc. Alternatively, these data can also be presented as 10.0 or 230.0 if a common expression such as  $\times 10^3$  is used in tables or figures. Avoid expressing data in 'lakhs', instead use 'thousand' or 'million'.
- 12.5 Only standard abbreviations should be used and these should invariably be explained at first mention. Avoid the use of self-made abbreviations such as Rhizo., Azo., buta, isop. etc. for *Rhizobium*, *Azotobacter*, butachlor, isoproturon, respectively.
- 12.6 For names of plant protection chemicals, the first letter of the name need not be capitalized for scientific names. Trade names should normally be avoided. All the names should be checked very carefully.
- 12.7 Use of unnecessary abbreviations and treatment symbols such as T<sub>1</sub>, T<sub>2</sub>, etc. under Materials and Methods or tables without actually using these under Results and Discussion should be avoided.
- 12.8 All weights and measurements must be in SI or metric units. Use kg/ha, or t/ha (if more than 999 kg/ha), but not q/ha. Similarly, prefer use of g/ha, mg/kg, mg/l, mg/g, ml/l etc. rather than % or ppm. Do not follow the style kg ha<sup>-1</sup> or t ha<sup>-1</sup>.
- 12.9 Use % after numbers, not per cent, e.g. 7%. In a series or range of measurements, mention the units only at the end, e.g. use 3, 10, 17, and 30°C; 20 or 30% more instead of 3°C, 10°C, 17°C, and 30°C; 20% or 30% more.
- 12.10 Numeral should be used whenever it is followed by a unit measure or its abbreviations e.g. 1 g, 3 m, 5 h, 6 months, etc. Otherwise, words should be used for numbers one to nine and numerals for larger ones except in a series of numbers when numerals should be used for all in the series.
- 12.11 For the composition of fertilizers, manures, crops, or soil, the elemental forms (K, P, Mg, etc.) should be used and not the oxides.
- 12.12 Application rates of fertilizer nutrients should not be mentioned in a proportion such as N : P<sub>2</sub>O<sub>5</sub> : K<sub>2</sub>O 120: 60: 40 kg/ha. It can be given as 120 kg N + 26.4 kg P + 33.3 kg K/ha.
- 12.13 Variety may be mentioned within single quotes such as 'Pusa Basmati', 'Pusa Vishal' etc.
- 12.14 Statistical analysis of data in the standard experimental design should be sound and complete in itself with both SEm $\pm$  and CD (P=0.05) values given for comparison of treatment means in tables and figures.
- 12.15 No change in authorship will be accepted once the article is submitted for consideration of its publication in the Journal.
- 12.16 Though authors can directly submit an article by mail or post, a forwarding letter from the controlling authority is necessary and the article will not be processed until the same is received.

### 13. Review Process

All the articles received for publication in *the Indian Journal of Agronomy* are given an identification number. For finding out the allotted the article number, the authors may visit our web site ([www.isa-india.in](http://www.isa-india.in)) a month after submission of the article. All the articles are initially screened by the Chief Editor solely or with the help of the Secretary and the members of the Editorial Board at the headquarters. If the article is found to be in order as per the 'Guidelines' and there is adequate original information, it is sent to an expert for peer review. On the contrary, the articles that are weak or are not conforming to 'Guidelines' are rejected as such or returned to the author for revision.

The authors may revise the article as per the comments by the incorporation of additional data and information. The resubmitted article (within a months' time) will be reviewed for improvement in contents. If the Editorial Board is satisfied with the revision, it will be sent to the reviewer. After the article has been examined by the reviewer, it will be suitably edited by a member of the Editorial Board. The comments of both the reviewer and the member of the Editorial Board along with the manuscript will be passed on to authors, who after attending to the suggestions will resubmit it. The thoroughly revised article will be checked by the Editorial Board and will be placed before the Chief Editor for a final decision. All the authors of the accepted article must be a member of the Indian Society of Agronomy. If any author is not a member, the article will remain pending for want of membership. The article accepted for publication by the Chief Editor will be checked by a professional editor for English language, uniformity, and any ambiguity before sending it to the press for composing. Proofs will be mailed to the corresponding author (as PDF file by e-mail or as hard copy by post) for checking and will also be checked by the professional editor/member of the Editorial Board. The Society does not levy any printing charges on the authors of articles published in the *Indian Journal of Agronomy*, and no reprints are supplied even when the author is willing to pay for the reprints.

### CHECKLIST

*Authors are requested to note the following point's before submission of the article:*

1. The article should contain data not older than 5 years on the date of receipt in the Society office.
2. All scientific or technical names as well as all data

- and facts must be rechecked carefully before submitting the manuscript.
3. Articles based on data of two or more seasons or years in cropping system mode, with proper statistical analysis, are encouraged. In such cases, seasonal or yearly variations should be clearly brought out through pooled analysis.
  4. Articles on newly-emerging areas such as resource-conserving techniques, agronomy of transgenic crops, organic farming, precision farming, integrated farming systems, sustainability issues, and other unexplored areas will be given priority.
  5. Routine studies on varietal evaluation, seed rate, spacing, sowing date, etc. will not be considered unless these provide some new information. Similarly, articles based on simple growth or yield attributes without any data on soil or plant analysis will not be considered.
  6. Economic analysis of data indicating total variable cost, net returns, benefit: cost ratio, etc. should be given, wherever required.
  7. In weed control experiments, information on specific weed flora, dry matter, nutrient uptake by weeds and crop, WCE, WI, etc. should be included.
  8. In nutrient management experiments, data on nutrient uptake, efficiency, residual soil fertility, nutrient balance, etc. are necessary.
  9. In dryland and irrigation studies, information on rainfall patterns, soil moisture status, consumptive use of water, root growth, WUE or water productivity, etc. should be included.
  10. In studies on intercropping systems, suitable indices like CEY, LER, RCC, aggressivity, competition index, etc. will add value to the information. Similarly, in cropping systems research, suitable indices should be given.
  11. The discussion becomes very weak when statements like "The results are in agreement with .....", "Similar results were reported by ....." are used. These should be avoided because they give the impression that nothing new was achieved in the reported study.
  12. Articles should be typed on one side of white A4 size paper, double-spaced throughout including abstract, references, and tables, leaving adequate margins on all sides to allow reviewer's or editor's remarks. All the pages should be numbered consecutively.
  13. Authors are not required to send floppy or CD on the first submission of the article. Only the revised version of the accepted article may be sent on the floppy, CD, or through Email.
  14. Authors are encouraged to send their articles through Email to save time and postage.
  15. All the contributing authors must be the members of Indian Society of Agronomy.
  16. To ensure the consideration of the submitted article, the authors are requested to present the information in a systematic and scientific manner, seeking help from their senior and experienced colleagues if necessary, because casually written manuscripts would be outright rejected.
  17. In exceptional cases where the authors feel that the comments made by the reviewer or the editor for recommending rejection of the article are not justified, they may send their counter-arguments with full justification. The Editorial Board will again seek the opinions of the expert as well as of another reviewer in such cases.
  18. Authors are expected to maintain high standards of integrity and ethics while submitting their articles. They should not hide any information or provide wrong information, and must not duplicate the information already published or submitted for publication elsewhere. It is also desirable that the fruits of research are shared suitably with other co-authors. Undue credit should not be given to anyone who has not made a notable contribution, nor should the name of any author excluded who has made significant contributions to the reported work.
  19. Type as per IJA format (New Times Roman, Font 12, Double spaced)
  20. Page numbering including tables and figures.
  21. All data pooled over 2-3 years of experimentation and provide pooled data in tables and text. Annual data only for dry land experiment over three years or experiment with cumulative effect.
  22. Research Communication based on M.Sc. work will be considered. These may be restricted to typed 4 pages including tables and figures (not more than 2 tables).
  23. Yield data in tonnes/ha (no q/ha or kg/ha).
  24. Data restricted to 3 significant digits (153, 15.3, 1.53, etc.). For gross and net returns use  $\times 10^3$  ₹/ha in the column heading and data given in thousand.
  25. SEm+ and CD in (P=0.05) given for each table.
  26. References—Cross check the text and bibliography. Check the year of publication carefully.
  27. The scientific name of each crop with authority in the abstract.
  28. Email ID of corresponding author and designation with the affiliation of each author as a footnote.

**Research articles providing comprehensive information based on recent experimentation and following all the instructions as per the 'Revised Guidelines for Contributors' will be immediately processed for publication in the Journal.**

*All correspondence should be addressed to the Secretary, Indian Society of Agronomy, Division of Agronomy, Indian Agricultural Research Institute, Pusa, New Delhi 110 012, India. [Telephone/Telefax: 0091-11-25842283; Email: secretary\_isa@hotmail.com]*

