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Research Paper

Performance of promising lentil (*Lens culanaris*) cultivars under zero-till condition for sustainable intensification of rice (*Oryza sativa*)–fallows in eastern India

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ABSTRACT

An experiment was carried out during the winter (*rabi*) seasons of 2017–18 and 2018–19 at Patna, Bihar, to identify the most suitable lentil (*Lens culinaris* Medikus) cultivars, which can perform better in zero-till condition of lowland rice (*Oryza sativa* L.)–fallow production system. Results revealed that, among the lentil cultivars, 'Pusa Masoor 5' (2.20 t/ha) had higher seed yield and remained at par with 'Pusa Vaibhav', 'IPL 81', 'HUL 57', 'Arun' and 'DPL 15'. With respect to economic feasibility, 'Pusa Masoor 5' resulted in significantly higher gross returns (₹123 × 10^3/ha), net returns (₹92 × 10^3/ha) and benefit: cost ratio (3.9), respectively, as compared to 'IPL 316', 'DPL 62', 'Ranjan' and 'K 75'. Thus 'Pusa Masoor 5' followed by 'Pusa Vaibhav' proved more stable and promising cultivars than the others in augmenting productivity as well as profitability under zero-till condition of rice–fallows production system of eastern India.

Key words: Eastern India, Lentil cultivars, Productivity, Rice-fallow, Zero-till

Lowland rainfed rice-growing areas that remain uncropped during the winter season are considered as rice–fallows (Ghosh *et al.,* 2016). Eastern regions of India account for ~84% of nation's total rice–fallows (11.7 million ha) (Singh *et al.,* 2017). Non-availability of sufficient water for timely irrigation, poor financial condition of the farmers, faster depletion of residual soil moisture after harvesting of rice and poor soil status are several causes in this region for being fallows (Kumar *et al.,* 2019 a). In addition, late harvesting of long-duration rice (150–160 days) causing hindrance for timely sowing of winter crops which in turn, exacerbates the moisture and temperature stresses in winter crops (Kumar *et al.,* 2018). Ever-increasing population has put tremendous pressure on agriculture production system for food and nutritional security (Zeliang *et al.*, 2020). Further, climate uncertainties and vulnerability aggravated these problems. Major cereals i.e. rice/ wheat, which are grown with heavy fertilization, irrigation and pesticides, have now reached in yield plateau (Kumar *et al.,* 2021a, b). In this context, despite many obstacles in rice–fallows, this area offers enormous opportunities to strengthen the food and nutritional security by employing effective soil/ crop/ moisture-management practices.

Selection of the suitable crop/ cultivars will also help in sustainability of crop intensification. Any short-duration crop can be brought under cultivation in rice–fallows, which are having ability to utilize moisture from deeper soil layers, low water requirement, and crop establishment by surface seeding, drought-resistant, resistance to several insects and diseases and survival ability in less-fertile soil (Kumar *et al.,* 2020 a, b). Pulses/ legumes are more adaptable and productive over oilseed crops under moisture limited environment of rice–fallows (Kumar *et al.,* 2019b). In India, pulses are considered as the poor man's only source of protein. Currently, India is the largest producer (25%), consumer (27%) and importer (14%) of pulses in the world (FAO, 2021). Depending on domestic shortfall in pulses production in 2016–17, nation has spent ₹23,550 million

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on import of pulses (*www.indiastatagri.com*). Introduction of pulses in these rice–fallows areas will help increase production as well as reduce dependency on import of pulses. Among the pulses, lentil is the second important winter legume crop of Indo-Gangetic Plains (IGP) in India. It is a primary constituent of native cropping sequences, and can be used as an excellent soil-fertility restorer (Singh *et al.,* 2015a, b). Further, early-maturing lentil varieties may also escape terminal moisture stress during winter (Erskine *et al.,* 2011). Thus, improved understanding in terms of varietal evaluation of lentil under the moisture limited condition of rice–fallows ecology will help us to select the appropriate cultivars to upscale the farmer's socio-economic status, achieving the nutritional and food security particularly in rice–fallow production system of eastern India. Therefore, the present study was undertaken.

MATERIALS AND METHODS

The present study was carried out at the ICAR–Research Complex for Eastern Region, Patna, Bihar (25°30'N, 85°15'E, 52 m above mean sea-level) during the winter (*rabi*) season of 2017–18 and 2018–19. Climate of the site is hot humid subtropical. Mean monthly maximum temperature and pan evaporation were recorded the highest in November month during both the years, whereas mean monthly minimum temperature was the lowest in January month of both the years. There was no rainfall during 2017–18, while during 2018–19 a negligible amount of 18 mm total rainfall occurred during the cropping. Overall, agro-climatic conditions of Research Farm were conducive for lentil cultivation. Initial status of the soil (0–15 cm depth) of experimental field was silty-clay loam (10.8% sand, 53.2% silt and 36.1% clay) in nature, low in organic carbon (0.48%) and available nitrogen (236 kg N/ha), high in available phosphorus (25.5 kg P/ha), medium in available potassium (277 kg K/ha) and neutral in soil reaction (*p*H 7.73). Experiment was laid out in a randomized block design (RBD) with 3 replications. Eleven lentil varieties, *viz.* 'HUL 57', 'DPL 62', 'Arun', 'DPL 15', 'Pusa Vaibhav', 'IPL 81', 'Ranjan', 'K 75', 'IPL 406', 'IPL 316' and 'Pusa Masoor 5' (Table 1), were evaluated under the residual moisture after harvesting of puddled transplanted rice. After rice harvesting, glyphosate (Roundup, 41% EC) at 1.5 L/ha was applied for controlling the weeds. Seeds were soaked for overnight (12 hours) in water before sowing, to obtain the uniform germination. Crop was sown with help of zero-till happy seeder at a spacing of 22.5 m × 10 cm and recommended dose of nutrients, i.e. 20 kg N + 50 kg P_2O_5/ha, was applied basal through diammonium phosphate (DAP). As a part of the nutrient management, foliar spray of 2% urea was done at flowering and grain-development stages. One hand-weeding was done at 35 days after sowing (DAS) to control the weeds. No irrigation was applied during cropping, since it was grown on the residual soil-moisture condition. Occurrence of phenological event (days taken to 50% flowering and physiological maturity) was recorded from each plot and average dates of these phenophases were used for analysis. Five randomly selected plants from each plot were taken at the harvesting for morphological attributes, i.e. plant height and root length.

Total root mass of 3 plants at flowering stages was dipped in water and kept in measuring cylinder for recording the root volume by water displacement method with help of thin thread. Displaced water (cm^3) was recorded to represent the volume of roots (Kumar and Kumawat, 2014). Randomly selected 2 m^2 area was harvested separately from each plot and sundried. After harvesting and threshing, seed yield was recorded and then it was adjusted at H"12% moisture content. Grain and biomass productivity was obtained by dividing the seed and biological yield of each cultivar with total cropping duration of respective cultivars. Gross returns (GR) were calculated on the basis of the minimum support price (MSP) of lentil declared by the Government of India and prevailing straw price in local market during the respective years. Net returns (NR) were calculated as difference between gross returns and total cost of cultivation. Benefit: cost ratio was worked out by dividing the gross returns with total cost of cultivation. Economic efficiency was obtained by dividing the net returns with total cropping duration of respective cultivars. All the recorded data were analyzed with the help of analysis of variance (ANOVA) technique using Indian NARS Statistical Computing Portal. The least significant difference test (LSD) was used for comparison of the treatment means at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Crop morphology

Among the lentil cultivars, 'IPL 406' remained at par with 'IPL 81', 'DPL 15', 'Pusa Vaibhav' and 'Arun' and showed the markedly higher plant height over rest of cultivars. While, 'IPL 316' being at par with 'K 75' noticed with the shortest plant (Table 2). 'DPL 62', 'Pusa Masoor 5', 'Pusa Vaibhav' and 'Ranjan' had considerably higher number of primary branches. Alike primary branches, 'DPL 62', 'Pusa Masoor 5' and 'K 75' had significantly higher secondary branches. Root length, volume and dry weight/plant of lentil significantly differed amid cultivars. Among the tested cultivars, 'IPL 81' followed by 'Ranjan' exhibited significantly higher for root length (Table 2). Markedly higher root volume was observed in 'Ranjan' (0.15 cm^3/plant), followed by 'K 75'. Further, 'K 75' cultivar, followed by 'Ranjan' also expressed remarkably higher root dry weight. However, 'IPL 316' showed significantly lower root dry weight. Variation in crop morphological attributes of lentil cultivars in zero tillage (ZT) with residual moisture could be due to their genetic makeup (Laik *et al.,* 2014).

Crop phenology

Days to 50% flowering (DFF) and days to physiological maturity (DPM) significantly varied among the tested cultivars (Fig. 1). Lentil cv. 'Ranjan' (66.3 days) being at par with 'Arun' (68 days), took significantly shortest time to reach 50% flowering stage. Earliest onset of physiological maturity was realized in 'Ranjan' (100.7 days), whereas, 'IPL 316', 'DPL 62', 'IPL 406' and 'IPL 81' were observed with delayed in attaining the physiological maturity (114.3, 113.7, 112 and 111.7 days, respectively). Significant differences in onset of days to 50% flowering and physiological maturity stages of different lentil cultivars were also reported by Yadav *et al*. (2015).

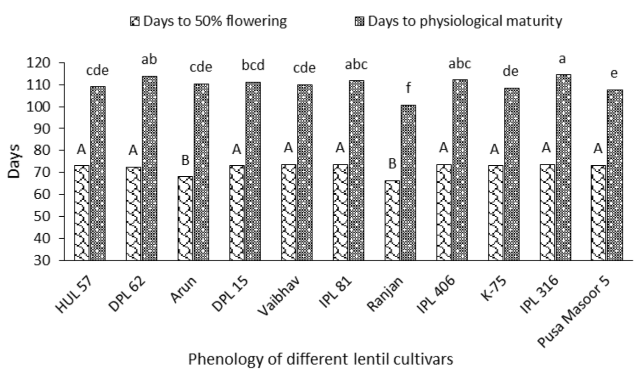

Fig. 1. Crop phenology of different lentil cultivars under rice–fallow production system of eastern India; Data followed by different uppercase and lowercase letters differ significantly (P=0.05) using least significant difference test for days to 50% flowering and days to physiological maturity, respectively

Yield attributes

Different tested lentil cultivars brought significant variations in yield attributes among themselves (Table 3). The maximum number of pods/plant was recorded with 'Pusa Masoor 5' followed by 'Pusa Vaibhav', while significantly the lowest number of pods was achieved in 'K 75' and 'DPL 62'. 'Pusa Masoor 5', followed by 'Ranjan' and 'DPL 62' resulted in noticeably higher seeds/pod. However, 'IPL 406' remained at par with 'IPL 81' and 'HUL 57' showed markedly lower seeds/pod. 'IPL 406' followed by 'HUL 57' recorded significantly higher 1,000-seed weight. However, 'DPL 62' and 'DPL 15' being at par with 'IPL 316' had significantly lower 1,000-seed weight than the other cultivars. Besides more branching, early attainment of flowering also ensured proper development of reproductive organs, i.e. pods/plant, seeds/pod, test weight; consequently higher yield attributes in respective cultivars.

Crop productivity

Among the tested varieties, 'Pusa Masoor 5' (2.20 t/ha) remained at par with 'Pusa Vaibhav', 'IPL 81', 'HUL 57', 'Arun' and 'DPL 15' and recorded significantly higher seed yield than to the other cultivars. 'Pusa Vaibhav' (6.8 t/ha), followed by 'Pusa Masoor 5' and 'IPL 81' (6.0 and 5.9 t/ha) recorded the higher biological yield. Different cultivars

Table 1. Details of promising lentil cultivars tested under the present study

Cultivars	Origin	Release year	Days of maturity	Average yield (t/ha)	Salient features
'HUL 57'	BHU, Varanasi	2005	120–125	1.4–1.5	Small seed, resistant to rust and moderately resistant to wilt
'DPL 62' (Sheri)	IIPR, Kanpur	1997	130–135	1.7–1.8	Large seeds, resistant to rust and wilt
'Arun' (PL 77-12)	RAU, Dholi, Bihar	1986	125–130	2.0–2.2	Medium large seed and tolerant to rust
'Priya' (DPL 15)	IIPR, Kanpur	1995	135–140	1.5–1.6	Large seed, resistant to rust and tolerant to wilt
'Pusa Vaibhav'	IARI, New Delhi	1996	130–135	1.7–1.8	Small seed, resistant to the rust
'IPL 81'	IIPR, Kanpur	2000	110–115	1.2–1.3	Large seed, tolerant to rust and wilt
'Ranjan' (B 256)	Behrampur (WB)	1982	120–125	1.8–2.0	Small seed and white flower
'IPL 406' (Angoori)	IIPR, Kanpur	2007	125–130	1.7–1.8	Extra-large seeds, resistant to rust
'Malika' (K 75)	CSAUA&T, Kanpur	1986	130–135	2.0–2.2	Medium seed, grey coloured and mottled
'IPL 316'	IIPR, Kanpur	2013	110–115	1.6–1.8	Large seed, brown with orange cotyledons and resistant to rust and tolerance to wilt
'Pusa Masoor 5'	IARI, New Delhi	2008	120–128	1.7–1.8	Moderately resistant to rust and pod borer

Source: AICRP on MULLaRP (2019)

BHU, Banaras Hindu University, Varanasi; IIPR: Indian Institute of Pulses Research, Kanpur; RAU: Dr. Rajendra Prasad Central Agricultural University, Tirhut College of Agriculture, Dholi, Bihar; IARI: Indian Agricultural Research Institute, New Delhi; CSAUA&T: Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, WB: West Bengal.

exerted significant influence on grain and biomass productivity (Fig. 2). ‘Pusa Masoor 5’ (17.8 kg/ha/day) being at par with ‘Pusa Vaibhav’, ‘IPL 81’, ‘Arun’ and ‘HUL 57’ showed markedly higher grain productivity than rest of the cultivars. Maximum biomass productivity was achieved with ‘Pusa Vaibhav’ (54.5 kg/ha/day) closely followed by ‘Pusa Masoor 5’ and ‘IPL 81’ (48.9 and 46.8 kg/ha/day). Higher pods/plant, seeds/pod and heavier weight of grains led to higher seed yield in these respective lentil cultivars (Yadav *et al*., 2015).

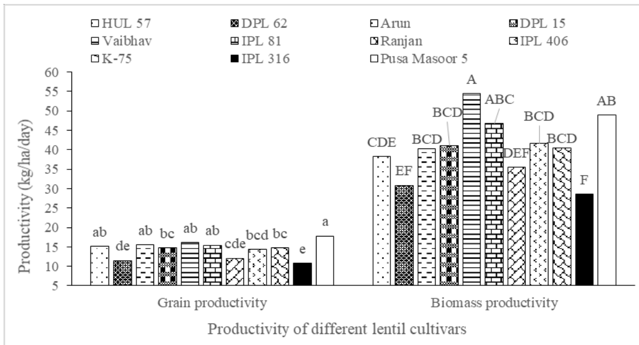

Fig. 2. Crop productivity of different lentil cultivars under rice–fallow production system of eastern India; Data followed by different lowercase and uppercase letters differ significantly (P=0.05) using least significant difference test for grain and biomass productivity respectively

Economics

Cultivation of lentil cv. ‘Pusa Masoor 5’ resulted in significantly higher gross returns (₹123 × 10^3/ha), net returns (₹92 × 10^3/ha) and benefit: cost ratio (3.9). Remaining cultivars were observed statistically equal for these economics attributes (Table 3). Maximum economic efficiency was noted in ‘Pusa Masoor 5’ (₹752/ha/day) compared to ‘IPL 316’, ‘IPL 406’, ‘DPL 62’,‘Ranjan’ and ‘K 75’. Further results revealed that, ‘Pusa Vaibhav’, ‘IPL 81’, ‘Arun’ and ‘DPL 15’ (₹714, 649, 616 and 591/ha/day respectively)

Table 2. Growth attributes of different lentil cultivars under rice–fallow production system of eastern India (pooled data of 2 years)

Cultivars	Plant height (cm)	Primary branches/ plant	Secondary branches/plant	Root length (cm)	Root volume (cm^3/plant)	Root dry weight/plant (g)
‘HUL 57’	43.0^{BC}	2.7^{DE}	7.0^{E}	9.9^{D}	0.08^{C}	1.4^{F}
‘DPL 62’	42.0^{BC}	4.0^{A}	14.3^{A}	12.9^{C}	0.07^{D}	1.6^{E}
‘Arun’	44.2^{ABC}	3.3^{BC}	12.3^{B}	6.3^{G}	0.04^{FG}	1.3^{F}
‘DPL 15’	45.8^{AB}	3.3^{BC}	10.0^{D}	6.8^{FG}	0.03^{H}	1.7^{D}
‘Pusa Vaibhav’	45.2^{AB}	3.7^{AB}	10.7^{CD}	10.2^{D}	0.03^{GH}	1.8^{C}
‘IPL 81’	45.8^{AB}	2.0^{F}	3.0^{F}	19.1^{A}	0.08^{C}	1.7^{CD}
‘Ranjan’	37.7^{D}	3.6^{ABC}	12.2^{BC}	14.0^{B}	0.15^{A}	2.7^{B}
‘IPL 406’	47.2^{A}	3.0^{CD}	9.3^{D}	10.2^{D}	0.04^{F}	1.6^{E}
‘K-75’	40.5^{CD}	2.3^{EF}	13.7^{AB}	7.6^{EF}	0.13^{B}	2.9^{A}
‘IPL 316’	36.8^{D}	2.0^{F}	10.0^{D}	8.3^{E}	0.08^{C}	1.2^{G}
‘Pusa Masoor 5’	42.2^{BC}	4.0^{A}	14.0^{A}	10.0^{D}	0.05^{E}	1.3^{F}

Table 3. Yields and economics of different lentil cultivars under rice–fallow production system of eastern India (pooled data of 2 year)

Cultivars	Pods/ plant	Seeds/pod	1,000-seed weight (g)	Seed yield (t/ha)	Biological yield (t/ha)	Gross returns (×₹10^3/ha)	Net returns (× 10^3₹/ha)	Benefit: cost ratio	Economic efficiency (₹/ha/day)
‘HUL 57’	68.2^{C}	1.4^{EF}	29.5^{B}	1.9^{AB}	4.7^{CDEF}	104^{AB}	72^{AB}	3.3^{AB}	590^{AB}
‘DPL 62’	24.7^{G}	2.2^{AB}	15.7^{F}	1.5^{CD}	3.9^{EF}	82^{CD}	51^{CD}	2.6^{CD}	403^{D}
‘Arun’	57.0^{D}	1.6^{DE}	19.6^{DE}	1.9^{AB}	5.0^{BCD}	108^{AB}	76^{AB}	3.5^{AB}	616^{AB}
‘DPL 15’	55.7^{D}	1.8^{CD}	17.2^{F}	1.9^{AB}	5.1^{BC}	105^{AB}	74^{AB}	3.4^{AB}	591^{AB}
‘Pusa Vaibhav’	75.0^{B}	1.8^{CD}	26.4^{C}	2.0^{AB}	6.8^{A}	120^{AB}	88^{AB}	3.8^{AB}	714^{AB}
‘IPL 81’	70.3^{C}	1.4^{EF}	20.0^{D}	1.9^{AB}	5.9^{AB}	113^{AB}	82^{AB}	3.6^{AB}	649^{AB}
‘Ranjan’	41.7^{E}	2.2^{AB}	17.1^{F}	1.4^{D}	4.1^{DEF}	80^{D}	49^{D}	2.6^{D}	424^{CD}
‘IPL 406’	31.3^{F}	1.2^{F}	36.3^{A}	1.8^{BC}	5.2^{BC}	103^{AB}	72^{AB}	3.3^{AB}	575^{BC}
‘K 75’	21.7^{G}	2.0^{BC}	24.7^{C}	1.8^{BC}	4.9^{BCDE}	102^{BC}	71^{BC}	3.3^{BC}	579^{BC}
‘IPL 316’	38.0^{E}	1.8^{CD}	17.6^{EF}	1.4^{D}	3.7^{F}	78^{D}	47^{D}	2.5^{D}	365^{D}
‘Pusa Masoor 5’	95.2^{A}	2.3^{A}	25.3^{C}	2.2^{A}	6.0^{AB}	123^{A}	92^{A}	3.9^{A}	752^{A}

Data followed by different capital letters differ significantly (P=0.05) using least significant difference test for separation of mean of a particular parameter were noticed statistically equal with each other and showed at par economic efficiency with 'Pusa Masoor 5'.

Our results indicated that, 'Pusa Masoor 5' followed by 'Pusa Vaibhav', 'IPL 81', 'HUL 57', 'Arun' and 'DPL 15' proved more stable and promising cultivars than the other tested cultivars of lentil in augmenting the productivity as well as profitability under zero-till condition of rice–fallow areas of eastern India. Thus, these cultivars can adapted for sustainable cropping intensification in rice–fallows of this region in particular and elsewhere with similar ecology.

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