Indian Journal of Agronomy **67** (2): 175–179 (June 2022)

Research Paper

Performance of promising linseed (*Linum usitatissimum*) cultivars under zero-till condition in rice (*Oryza sativa*)–fallows of Eastern India

RAKESH KUMAR[1], GOVIND MAKARANA[2], J.S. MISHRA[3], HANSRAJ HANS[4], A.K. CHOUDHARY[5], A.K. BISWAS[6], PRAVIN KUMAR UPADHYAY[7] AND UJJWAL KUMAR[8]

ICAR-Research Complex for Eastern Region, Patna, Bihar, 800 014

Received: August 2021; Revised accepted: April 2022

ABSTRACT

An experiment was conducted during the winter (*rabi*) season of 2017–18 and 2018–19 at the ICAR–Research Complex for Eastern Region, Patna, Bihar to identify the most suitable linseed (*Linum usitatissimum* L.) cultivars/ lines in rice (*Oryza sativa* L.)–fallow system. Amongst the linseed cultivars, 'Uma' (1.28 t/ha) was noted at par with 'RLC 143' (1.21 t/ha) and showed significantly highest seed yield compared with the other tested cultivars. With respect to the economic feasibility, linseed cv. 'Uma' linseed being at par with 'RLC 143' and showed significantly highest gross returns (₹51.3×10^3/ha), net returns (₹31.0×10^3/ha), benefit: cost ratio (2.5) and economic efficiency (₹240/ha/day) compared with rest of the cultivars. Thus, linseed cv. 'Uma' and 'RLC 143' exhibited a promising option to augment the productivity as well as profitability of rice–fallows areas of eastern India.

Key words: Cultivars, Eastern India, Linseed, Rice–fallow, Zero-till

Oilseed sector plays an important role in Indian agriculture. There is wide gap in supply and demand of edible oilseeds, contributing to an increasing reliance on import. To reduce dependency on import, production of oilseed must be raised by following some sustainable measures (Meena *et al.,* 2011a). In this context, rice–fallows, a lowland rainfed rice-growing areas that remain uncropped in winter season offers an enormous opportunity through cropping intensification (Kumar *et al.,* 2020). Eastern region of India accounts for ~84% of nation total rice–fallows (11.7 million ha) (Singh *et al.,* 2017; Kumar *et al*., 2021). Non-availability of sufficient water for timely irrigation, poor-financial condition of 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*., 2019a).

In addition, late harvesting of long-duration rice causes hindrance for timely sowing of winter crops which, in turn, exacerbates the moisture and temperature stresses in winter crops (Kumar *et al.,* 2018). Yields of major cereals (rice and wheat), which are grown with heavy fertilization, irrigation and pesticides, have already reached the plateau (Kumar *et al*., 2021). Any short-duration pulse or oilseed crop can be brought under cultivation in rice–fallows, which are having ability to utilize moisture from deeper soil layers, low-water requirement, crop establishment by surface seeding, drought-resistance, resistance to several insects and diseases and survival ability in less-fertile soil (Kumar *et al.,* 2018). Oilseed crops, i.e. Indian mustard and linseed, are adaptable for moisture-limited environment of rice–fallows for sustainable cropping intensification in eastern region of India (Kumar *et al*., 2019b). Oilseed crops has high potential for improving human diets, preventing malnutrition and providing jobs; thus considered as promising crops. Among winter oilseeds in India, linseed is considered the second most important oilseed crop after rapeseed-mustard. It is considered as a medicinal plant, besides providing oil (41%), protein (20%), and dietary fibre (28%) (Kumar *et al.,* 2018). Linseed also contains a high proportion of essential fatty acids, 75% polyunsaturated fatty acids, 57% alpha-linolenic acid (omega-3 fatty acid) and 16% linoleic acid (omega-6 fatty acid) (Soni *et al.,* 2016). It can be cultivated in marginal lands under diverse agro-climatic condition with assured crop harvest (Meena *et al.,* 2011c). Short-duration, drought resistance, fast-growing with limited external resources, fewer pests

[1]Corresponding author's Email: rakeshbhu08@gmail.com
[1]Senior Scientist (Agronomy), [2]Scientist, (Agronomy), [4]SRF, Consortium Research Platform (CRP) on Conservation Agriculture (CA), [5]Principal Scientist and Head (Acting), Division of Crop Research, [8]Director (Acting), ICAR-Research Complex for Eastern Region, Patna, Bihar 800 014; [3]Director, ICAR-Directorate of Weed Research Jabalpur, Madhya Pradesh 482 004; [6]Principal Scientist and Head, Soil Chemistry and Fertility Division, ICAR-Indian Institutes of Soil Science, Bhopal, Madhya Pradesh 462 038; [7]Scientist (Agronomy), Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi 110 012

and diseases incidence and long storability of grain are unique virtues favouring for introduction of linseed in rice–fallow (Singh *et al.* 2018; Zeliang *et al.*, 2020). Despite various potential benefits of linseed, its productivity is very low due to poor inputs management (Kumar 2017). Selection of suitable cultivars will help in sustainability of cropping intensification in rice–fallow. Thus, an improved understanding in terms of varietal evaluation of linseed under limited moisture condition of rice–fallow ecology will help us to select an appropriate cultivars to upscale the farmer's socio-economic status, as well as reduce the dependency on import *vis-à-vis* achieving the nutritional security. Therefore, the present study was undertaken to evaluate the performance of promising linseed cultivars in rice–fallow system of eastern India.

MATERIALS AND METHODS

The present study was carried out at ICAR–Research Complex for Eastern Region, Patna (25°30‘N, 85°15‘E, 52 m above mean sea-level) during the winter (*rabi*) seasons of 2017–18 and 2018–19. The climate of site is hot humid sub-tropical. Mean monthly maximum temperature and pan-evaporation was recorded highest in November during both the year, whereas, the mean monthly minimum temperature was the lowest in January of both the years. No rainfall was received in 2017–18, while in 2018–19 a negligible amount of 18 mm rainfall occurred during cropping period. Initial status of soil (0–15 cm) of experimental field was silty-clay loam (10.7% sand, 53.3% silt and 36.2% clay) in nature, low in organic carbon (0.46%) and available nitrogen (234 kg N/ha), high in available phosphorus (25.8 kg P/ha), medium in available potassium (275 kg K/ha) and neutral in soil reaction (*p*H 7.71). The experiment was laid out in a randomized block design with 3 replications. Eleven linseed cultivars/lines, viz. 'RLC 133', 'RLC 138', 'SLS 79', 'RLC 143', 'Uma', 'Indu', 'BAU 06-03', 'BAU 2012-1', 'BAUP 101', 'JLS 95' and 'Shekhar' were evaluated in residual moisture after harvesting of puddle transplanted rice (Table 1). After rice harvesting, glyphosate at 1.5 L/ha was applied for controlling weeds. Before sowing, to obtain uniform germination, seeds were water-soaked for overnight (12 h). The crop was sown with help of zero-till happy seeder with a following a spacing of 22.5 cm × 10 cm.

A common recommended dose of nutrients, i.e. 60 kg N + 40 kg P_2O_5/ha +40 kg K_2O/ha, was applied in all the cul-

Table 1. Details of promising linseed cultivars/lines tested during the study

Cultivars/ lines	Origin	Days of maturity	Average yield (t/ha)	Salient features
Promising lines				
'RLC 138'	IGKV, Raipur	–	–	–
'SLS 79'	JNKVV, Jabalpur	–	–	Suitable for rainfed situations
Cultivars				
'Chattisgarh Alsi 1'	IGKV, Raipur	–	–	Suitable for rainfed situations
'Utera Alsi'	IGKV, Raipur	118	0.57	Suitable for moisture stress winter (*rabi*) season, i.e. rice-based relay cropping ecosystem, moderately resistant to bud fly
'Uma'	CSAUA&T, Kanpur	123–135	0.87	Suitable for rainfed condition, tolerant to wilt, alternaria blight and rust
'Indu'	CSAUA&T, Kanpur	134–140	0.96	Suitable for irrigated areas, resistant to rust, powdery mildew and bud fly
'Divya'	BAU, Kanke, Ranchi	127–130	1.54	Highly resistant to rust, moderately resistant to alternaria blight, powdery mildew and wilt. It is also moderately resistant to bud fly under natural and artificial condition
'Priyam'	BAU, Kanke, Ranchi	128–130	1.25	Suitable for rainfed and moderate fertility conditionduring *rabi* season, highly resistant to bud fly and rust
'Sabour Tisi 1'	BAU, Sabour	120–122	1.3	Suitable for timely sown under utera/rainfed/high/low fertility condition during *rabi* season, moderately resistant to alternaria blight and bud fly
'Jawahar Linseed Sagar 95'	JNKVV, Jabalpur	113–133	1.01	Suitable for rainfed farming, resistant to rust and moderately resistant to wilt
'Shekhar'	CSAUA&T, Kanpur	–	1.2-1.3	Suitable for late sowing, highly adapted to rainfed condition, resistant to powdery mildew and bud fly, tolerant to alternaria blight and wilt

IGKV, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh; JNKVV, Jawahar Lal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh; BAU, Kanke, Ranchi, Jharkhand (Birsa Agricultural University); CSAUA&T, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh; BAU, Sabour, Bhagalpur, Bihar (Bihar Agricultural University) tivars. Diammonium phosphate (DAP) and muriate of potash (MoP) fertilizers were applied basal to supply P and K, respectively, whereas N was applied through urea after subtracting N amount supplied in form of DAP as basal and foliar spray at flowering and grain-development stages. One hand-weeding was done 35 days after sowing (DAS) to control the weeds. No irrigation was applied during the entire cropping period. The 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 plants from each plot were taken for studying the 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 root volume by displacement of water method with help of thin thread. Displaced water (cm^3) was recorded to represent volume of root (Kumar and Kumawat, 2014). Randomly selected 2.0 m^2 area was harvested separately from each plot and sun-dried. After harvesting and threshing, seed yield was recorded and then it was adjusted at 12% moisture content. Production efficiency was obtained by dividing the seed yield of each cultivar with total cropping duration. Gross returns (GR) were calculated based on prevailing linseed price in local market in respective years. Net returns (NR) were calculated as difference between GR and total cost of cultivation (CoC). Benefit: cost ratio was worked out by dividing GR with total CoC. The economic efficiency was obtained by dividing NR with total cropping duration. All collected data were analyzed with help of analysis of variance (ANOVA) technique of randomized block design (RBD). The least significant difference test (LSD) was used for comparison of treatment means at 5% level of significance ($P \leq 0.05$).

RESULTS AND DISCUSSION

Crop morphology

Among linseed cultivars, 'Uma' (59.9 cm) being at par with 'BAU 06-03' (56.3 cm) had markedly taller plant (Table 2). However, at harvesting, 'Uma', 'BAU 06-03' and 'BAU 2012-1' (68.4, 66.7, 66.7 cm, respectively) were statistically at par with 'JLS 95' (63.3 cm) and had taller plant than the other tested cultivars. Root length and volume of linseed cultivars significantly differed amid cultivars/lines at flowering stage (Table 2). 'Indu' (12.1 cm) and 'RLC 138' (11.8) had significantly longer root than rest of the cultivars/lines. 'RLC 138' (0.23 cm^3/plant) followed by 'Shekhar' and 'JLS 95' had significantly higher root volume as compared to the other cultivars. However, 'BAU 2012-1' (0.04 cm^3/plant) had the minimum root volume. 'JLS 95' (3.4 g) was at par for root dry weight/plant with 'SLS 79' and 'BAUP 101' compared with rest of the cultivars/lines. 'RLC 138' (2.0 g), followed by 'SLS 79' (0.9 g) and 'BAU 06-03' (0.9 g) gave significantly more dry weight/plant at flowering stage. Variation in crop morphological attributes of linseed cultivars in ZT with residual moisture could be due to their genetic makeup (Kumar *et al.,* 2019).

Crop phenology

The results revealed that, days taken to attain 50% flowering and physiological maturity significantly varied among the tested cultivars/ lines (Table 2). 'RLC 133' (73.0 days) remained at par with 'RLC 138', 'RLC 143' 'BAU 2012-1' 'JLS 95' and 'Shekhar' took significantly shorter time to reach days to 50% flowering compared to rest of the cultivars. The physiological maturity was witnessed earliest in 'RLC 143' (111.3 days), whereas 'BAU 06-03'

Table 2. Growth and phenological attributes of linseed cultivars/lines under zero-till rice–fallow system (pooled data of 2 years)

Cultivars/lines	Plant height (cm)*	Plant height (cm)#	Root length (cm)*	Root volume (cm^3/plant)*	Days to 50% flowering	Days to physiological maturity
'RLC 133'	53.3^{BCD}	58.7^{BC}	5.5^{G}	0.09^{E}	73.0^{E}	117.0^{DEF}
'RLC 138'	51.4^{CDE}	53.8^{CD}	11.8^{A}	0.23^{A}	73.3^{DE}	116.3^{F}
'SLS 79'	54.3^{BCD}	56.2^{CD}	8.7^{DE}	0.09^{E}	75.0^{BCD}	118.7^{BCDE}
'RLC 143'	47.8^{E}	52.5^{D}	3.2^{H}	0.05^{F}	73.7^{DE}	111.3^{G}
'Uma'	59.9^{A}	68.4^{A}	9.6^{C}	0.02^{H}	75.0^{BCD}	119.0^{BCD}
'Indu'	52.7^{BCD}	57.9^{C}	12.1^{A}	0.09^{DE}	75.7^{BC}	120^{B}
'BAU 06-03'	56.3^{AB}	66.7^{A}	6.5^{F}	0.10^{CD}	90.3^{A}	124.7^{A}
'BAU 2012-1'	52.8^{BCD}	66.7^{A}	10.9^{B}	0.04^{G}	74.0^{CDE}	116.7^{EF}
'BAUP 101'	51.1^{DE}	56.7^{CD}	9.7^{C}	0.09^{E}	76.0^{B}	117.7^{CDEF}
'JLS 95'	55.5^{BC}	63.3^{AB}	8.6^{E}	0.11^{C}	74.3^{BCDE}	119.7^{BC}
'Shekhar'	41.7^{F}	58.3^{BC}	9.3^{CD}	0.14^{B}	74.3^{BCDE}	119.0^{BCD}
SEm±	1.5	1.7	0.2	0.00	0.6	0.8
CD (P=0.05)	4.3	5.2	0.7	0.01	1.7	2.3

*At flowering; #At harvesting; Data followed by different capital letters differ significantly ($P \leq 0.05$) using least significant difference test for separation of mean of a particular parameter

(90.3 and 124.7) took the longest time to attain 50% flowering and physiological maturity respectively.

Yield attributes

Different linseed cultivars/ lines exhibited significant variations in yield attributes among themselves (Table 3). Linseed cv. 'BAU 2012-1' (47.8), followed 'BAUP 101' (43.8) and 'SLS 79' (41.6) had markedly higher number of capsules/plant. Significantly higher number of seeds/capsule was noted in linseed cv. 'BAU 06-03' (9.8) and 'RLC 133' (13.4 g) followed by 'BAU 06-03', 'BAU 2012-1' and 'RLC 143' (10.9, 9.1 and 8.9 g respectively) recorded markedly higher 1,000-seed weight over the remaining cultivars/lines, whereas 'SLS 79' (4.6 g) was found significantly lowest 1,000-seed weight. Enhanced cell-division, cell-elongation and tissue differentiation might be the possible cause for enhanced yield attributes of the respective cultivars. Kumar *et al.,* (2019c) also observed significant variations among tested linseed cultivars.

Crop productivity

Among the tested varieties/ lines, linseed cv. 'Uma' (1.28 t/ha) remained at par with 'RLC 143' (1.21 t/ha) and significantly higher for seed yield compared to rest of the cultivars/lines (Table 3). Cultivar 'BAU 2012-1' (0.98 t/ha) was statistically at par with 'Indu' and 'Shekhar' and had markedly lower seed yield. Linseed cv. 'BAU 06-03' (4.47) followed by 'Uma' and 'Indu' (3.81 and 3.69 t/ha) resulted in significantly higher stalk yield over the other tested cultivars. Biological yield was also markedly higher in linseed cv. 'BAU 06-03' (5.66 t/ha) (Table 3). Cultivar 'RLC 133' (29.9%), being at par with 'RLC 138' and 'BAUP 101' showed higher harvest index (HI) than rest of cultivars. However, linseed cv. 'BAU 06-03' (21%) remained at par with 'Indu'. Linseed cv. 'RLC 143' and 'Uma' (10 and 9.9 kg/ha/day respectively), being at par with 'RLC 138' (9.3 kg/ha/day), showed markedly higher production efficiency than rest of lines and cultivars (Fig. 1).

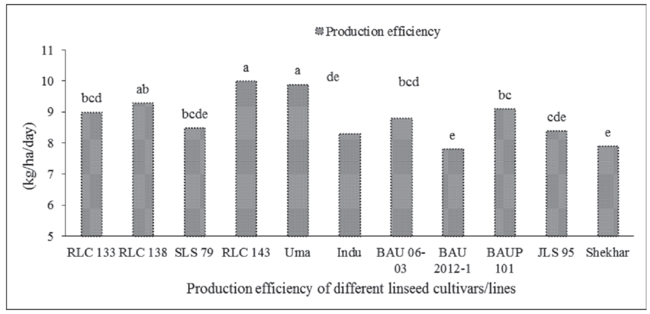

Fig. 1. Production efficiency of different linseed cultivars/ lines under zero-till rice–fallow system of eastern India; Data followed by different lowercase letters differ significantly ($P \leq 0.05$) using least significant difference test

Better morphological attributes, i.e. height and root length, in linseed cultivars, viz. 'BAU 06-03', 'Uma' and 'Indu' might have helped in absorption of water and nutrients from deeper layer and better partitioning of photosynthates in reproductive organ; thus, higher yield (Kashyap *et al.*, 2018).

Economics

Gross returns, net returns, benefit: cost ratio and economic efficiency were significantly influenced by different cultivars/ lines (Table 3). Linseed cv. 'Uma' being at par with cv. 'RLC 143' gave in significantly highest gross returns (₹51.3 × 10^3/ha), net returns (₹31 × 10^3/ha), benefit:

Table 3. Yield attributes, yield and economics of linseed cultivars/lines under zero-till rice–fallow system (pooled data of 2 year)

Cultivars/ lines	Capsules/ plant	Seeds/ capsule	1,000-seed weight (g)	Seed yield (t/ha)	Stalk yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Gross returns (₹×10^3/ha)	Net returns (₹×10^3 /ha)	Benefit: cost ratio	Economic efficiency (₹/ha/day)
'RLC 133'	24.2^{G}	6.8^{D}	13.4^{A}	1.15^{BCD}	2.68^{F}	3.83^{F}	29.9^{A}	45.9^{BCD}	25.6^{BCD}	2.3^{BCD}	201^{BCD}
'RLC 138'	27.8^{F}	8.0^{C}	6.0^{F}	1.17^{BC}	2.88^{EF}	4.06^{EF}	28.9^{AB}	46.9^{BC}	26.7^{BC}	2.3^{BC}	211^{ABC}
'SLS 79'	41.6^{C}	6.2^{D}	4.6^{G}	1.09^{CDE}	3.20^{CD}	4.30^{DE}	25.5^{C}	43.8^{CDE}	23.5^{CDE}	2.2^{CDE}	183^{CDE}
'RLC 143'	35.8^{DE}	8.6^{BC}	8.9^{C}	1.21^{AB}	3.42^{C}	4.63^{CD}	26.2^{BC}	48.4^{AB}	28.1^{AB}	2.4^{AB}	232^{AB}
'Uma'	43.6^{B}	6.6^{D}	7.5^{DE}	1.28^{A}	3.81^{B}	5.09^{B}	25.2^{CD}	51.3^{A}	31.0^{A}	2.5^{A}	240^{A}
'Indu'	35.6^{DE}	6.4^{D}	7.9^{D}	1.07^{DEF}	3.69^{B}	4.76^{BC}	22.6^{DE}	43.0^{DEF}	22.7^{DEF}	2.1^{DEF}	175^{DEF}
'BAU 06-03'	36.6^{D}	9.8^{A}	10.9^{B}	1.18^{BC}	4.47^{A}	5.66^{A}	21.0^{E}	47.3^{BC}	27.1^{BC}	2.3^{BC}	201^{CD}
'BAU 2012-1'	47.8^{A}	8.8^{B}	9.1^{C}	0.98^{F}	3.03^{DE}	4.01^{EF}	24.5^{CD}	39.3^{F}	19.0^{F}	1.9^{F}	150^{F}
'BAUP 101'	43.8^{B}	8.0^{C}	7.8^{D}	1.16^{BCD}	2.86^{EF}	4.02^{EF}	28.9^{AB}	46.5^{BCD}	26.2^{BCD}	2.3^{BCD}	205^{BCD}
'JLS 95'	35^{E}	8.0^{C}	8.1^{D}	1.09^{CDE}	3.01^{DE}	4.11^{EF}	26.7^{BC}	43.7^{CDE}	23.5^{CDE}	2.2^{CDE}	181^{CDE}
'Shekhar'	27.8^{F}	6.4^{D}	6.9^{E}	1.02^{EF}	3.05^{DE}	4.06^{EF}	25.1^{CD}	40.7^{EF}	20.5^{EF}	2.0^{EF}	159^{EF}
SEm±	0.5	0.2	0.2	0.03	0.08	0.12	0.9	1.3	1.3	0.1	10.4
CD (P=0.05)	1.5	0.6	0.7	0.09	0.23	0.35	2.8	3.9	3.9	0.2	30.7

Data followed by different capital letters differ significantly ($P \leq 0.05$) using least significant difference test for separation of mean of a particular parameter cost ratio (2.5) and economic efficiency (₹240/ha/day) compared to rest of cultivars/lines. Linseed 'BAU 2012-1' remained at par with 'Shekhar' and 'Indu' and showed significantly lower economics attributes. Our results are in close conformity with the findings of Kumar *et al.*, (2019c).

Based on the present results, it can be inferred that linseed cv. 'Uma' and 'RLC 143' proved promising under zero-till, moisture limited condition in rice–fallow of Eastern India. Therefore, these cultivars may be adopted to augment productivity as well as profitability of this region and elsewhere with similar ecology.

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