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RESPONSE OF LINOLA (*LINUM USITATISSIMUM* L.) TO DIFFERENT SPACINGS UNDER RAINFED CONDITIONS

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ABSTRACT. An experiment was conducted according to randomized complete design to determine best plant spacing and agronomic traits at research farm PMAS Arid Agriculture University Research Farm Chakwal Road, Rawalpindi, during 2008-2009. Three plant spacing's (5, 10, 15 cm) and three row spacing's (10, 20, 30 cm) comprised of the following treatment combinations (T1= 5×10 cm, T2= 5×20 cm, T3= 5×30 cm, T4= 10×10 cm, T5= 10×20 cm, T6= 10×30 cm, T7= 15×10 cm, T8= 15×20 cm, T9=15×30 cm) under rain-fed conditions. The net plot size was 2×6 m with three replications. Days to emergence, plant height at maturity, number of branches per plant, number of capsules per plant, number of seed per capsule, 1000-seed weight, seed capsule ratio, seed yield per plot, biological yield, harvest index, oil concentration and fresh weight of weeds was observed. All agronomic attributes were significantly effected at 15×30 cm spacing, along with oil concentration and fresh weight of weeds, while 10×10 cm row to row and plant to plant spacing had no significant effect. Plant height (cm), number of capsules per plant was maximum for plant geometry of 15×30 cm and lesser amount of weeds. An increase in row and plant spacing led to significantly higher of branching. Higher plant and row spacing resulted in non- consistent increase in the number of seeds per capsule. Seed yield increased with higher row to row and plant to plant spacings. Yield were lower at the narrow (10×10 cm) row and plant spacing's, compared to higher of 15×30 cm spacing. Thus, it is concluded from this study that Linola should be grown at 300-450 cm grids for higher yield output.

Keywords: linola; line spacing; row spacing; oil contents.

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INTRODUCTION

A new form of linseed known by the generic crop named Solin, which produces high-quality edible polyunsaturated oil similar in composition to sunflower oil. The Linola (*Linum usitatissimum* L.) is classified in the family *Linaceae*. It has a golden yellow seed, high in protein and produces oil, which is suitable for human consumption and the meal left after the extraction of oil from the seed can also be used in stock concentrates (Green and Paul Dribnenki, 1994). It was developed and released in Australia in 1992 and first commercially grown in 1994. Linola substitutes for flax in cropping rotations (Haumann, 1990; Weiss, 1993). It is claimed to have lower production costs than canola, but brings prices comparable to canola or other edible oils. Linola is Generally Recognized as Safe (GRAS) by the Food and Drug Administration (CRS Report, 2005). To make an edible linseed oil, the fatty acid composition has been changed and linolenic acid (C 18:3) has been substantially reduced from 50 % to 2 %, through genetic mutation. These low linolenic acid mutants have greatly elevated levels of linoleic acid, 65–76%. This reduction in linolenic acid greatly increases the oxidative stability of the oil. It becomes an edible polyunsaturated oil almost identical to sunflower in fatty acid composition. Genetic modification of the activity of desaturase enzymes blocks the conversion of double-unsaturated linoleic acid (C 18:2) into triple-unsaturated linolenic acid (C 18:3) in the developing seed. This creates low-linolenic mutants with very high levels of linoleic acid (Askew, 1992). The meal left after extraction of oil from Linola seed is a valuable source of protein and energy for animal feeding. Linola meal can therefore be used wherever linseed meal is currently used in animal feeding, and is particularly suitable for ruminant feeding (cattle, goats and sheep). But there is an issue with its digestibility for the non-ruminants because of the presence of higher contents of a soluble fiber, which is known as mucilage and therefore lessens its energy yield importance as a regular meal for pigs and poultry. Research is being carried out to completely remove the mucilage contents and harvest the Linola meal that is appropriate for addition at sensible levels in pig and poultry foods (Green, 1995).

Although Linola can be regarded as a "new crop", agronomically and botanically it is very similar to linseed. It matures at the same time as flax or oil crops. Linola is compatible with cereal production systems and can be harvested with the same machinery that is used for cereals and other small grain crops. The harvest dates for Linola range from 170 to 210 days after sowing and this may pose problems for their inclusion in a cereal rotation, particularly in Northern temperate latitudes, where growing seasons are shorter. Linola can be grown wherever flax and linseed varieties currently perform well, also in many areas where cereals are grown. Linola is better adapted to cooler environments, than other polyunsaturated oilseed crops, such as sunflower and maize, thus providing an opportunity to produce highly polyunsaturated oil in more Northern latitudes. It clashes with the sunflower market, but is more adapted to Northern Europe than sunflower (Askew, 1992). The crop produces light golden oil with excellent oxidative stability. Ground Linola seed shows considerable promise as a functional food component of flour in baking tests for improving bread quality and shelf life. The seed contains mucilage, linked to reduced blood cholesterol, and it is a rich source of lignans, a group of anti-carcinogenic compounds. The seed meal can be used in ruminant feeds in the same way as linseed meal (Green, 1995).

Linola also shows compensatory mechanisms although the precise nature of the plant's response to differences in available space is less well documented, especially for the newer, higher yielding cultivars. Effects on dry matter accumulation (Freer, 1992), plant height (Gubbels, 1978) and basal branch production (Freer and Sansome, 1991) are documented in the literature. In addition, overall effects of plant density on seed yield have been reported, which suggest a range of optimum densities of 250 plants m^{-2} (Gubbels and Kenaschuk, 1989), 424 - 606 m^{-2} (Taylor and Morrice, 1991), 300 - 900 plants m^{-2} (Turner, 1987) and 346-713 plants m^{-2} (Freer, 1992). The variation is likely to be the result of other confounding factors, e.g. sowing date, season, disease incidence, and not simply a plant spacing effect. One of the challenges be setting the economy of Pakistan is the edible oil deficit. Its indigenous production is below the consumption levels with a very wide gap between production and consumption. The inflexible cropping system, competition of oilseeds with main crops i.e., wheat, cotton, rice etc., the availability of seed and disease problems and other socio-economic problems are the major causes of this gape, which is bridged through import of huge quantity of edible oil by spending huge amount of foreign exchange, as in the year 2008, about 1.29 million tons of edible oil was imported (Economic Survey of Pakistan, 2008). Considering the socio-economic and technical problems faced by this crop, some alternate need to be looked into. The horizontal expansion of area under oilseed in irrigated, as well as rain fed area seems to be impossible. The available option in rain fed areas is the Kharif fallowed land, those essentially are kept fallow to restore fertility etc. If some hard crops those require less moisture and nutrients are tried, may bring some reasonable benefits for farmers. Linola may be one of such alternative crops. Keeping in view the potential of *Linum usitatissimum* and problem being faced by the farmers to grow other oilseed crops (linseed), the present study was planned with the objective to record the response of Linola (*Linum usitatissimum* L.*)* to different agro management techniques.

MATERIALS AND METHODS

Field experiment was conducted at Koont Research Farm, PMAS Arid Agriculture University, Rawalpindi, to find the effect of agro management practices on Linola, during Rabi 2008-2009. The experiment was laid out in randomized complete block design with three replications. Prior to sowing land was fallow during summer. At the end of rainy season soil was ploughed with cultivator. At the time of last plowing recommended dose of NPK (70:50:0) was applied to the soil. The average rainfall and mean temperature values during the experiment are presented in the *Table 1*. The planting geometry was tested by maintaining three row spacings and three plant spacings. Each plot was of 2.5 m length and 0.9 m width. Experiment comprised of following treatment combinations: T1=5×10 cm, T2=5×20 cm, T3=5×30 cm, T4=10×10 cm, T5=10×20 cm, T6=10×30 cm, T7=15×10 cm, T8=15×20 cm, T9=15×30 cm. The sowing was done by pora method with hand on 22-10-08 with 15 kg ha^{-1} seed rate. Weeds were kept under control manually as and when needed. The experiment was harvested on 19-05-09. Following observations, during this experiment were recorded by standard procedure: days to emergence, plant height at maturity (cm), plant height at maturity (cm), number of capsules per plant, number of seeds per capsule, seed capsule ratio, 1000-seed weight (g), biological yield (kg ha^{-1}), seed yield (kg ha^{-1}), harvest index (%), seed oil concentration (%). Oil concentration in seed was determined by using NMR analyzer. Fatty acids (palmitic acid, stearic acid, oleic acid, linoleic acid and α linolenic acid etc.) composition was determined by gas chromatography (GC). All weeds present in the 50 cm row length of two central rows were removed and were weighed to record fresh weight of weeds ((kg m^{-2}).

Table 1 - Total rainfall and mean temperature during the experiment 2008-2009

Month	Rainfall (mm)	Mean Min. temp. (^{0}C)	Mean Max. temp. (^{0}C)	Mean temp. (^{0}C)
October	24.5	18.4	32.4	26.5
November	2.3	9.7	28.4	18.56
December	55.9	7.5	22.3	14.3
January	66.7	7.9	19.5	13.1
February	34.5	8.2	22.3	15.2
March	29.3	12.4	27.1	19.6
April	75.3	11.5	32.3	22.7

Statistical analysis

The data were subjected to analysis of variance using MSTAT-C software and means were compared with the Least Significant Difference (LSD) test at 5% level of probability (Chase and Bown, 1997).

RESULTS AND DISCUSSION

Data regarding days to emergence, plant height, number of basal branches per plant, number of fruit bearing branches per plant, number of capsule, number of seeds per capsule, 1000-seeds weight was presented in *Table 2.*

Plant height reflects the growth behavior of a crop, besides genetic characteristics, soil nutrients status and environmental condition under which it is grown. Planting geometry of a crop plays a key role in determining the height of the plants.

Table 2 - Days to emergence, plant height, number of basal branches per plant, number of fruit bearing branches per plant, number of capsules per plant, number of seeds per capsules, 1000 seed weight are affected by plant to plant and row to row spacing.

Treatments	Days to emergence	Plant height	No. of basal branches per plant	No. of fruit bearing branches per plant	No. of capsules per plant	No. of seeds per capsule	1000-seed wt.
T1 (5x10 cm)	11.83 NS	81.96 a	23.54 d	225.8 f	8.460 NS	8.460 NS	5.560 NS
T2 (5x20 cm)	10.98	69.74 bc	25.43 d	241.1 def	8.633	8.633	5.467
T3 (5x30 cm)	12.56	74.38abc	30.59 bc	261.2 cd	8.957	8.957	5.757
T4 (10x10 cm)	10.95	69.24 bc	25.81 d	235.8 ef	8.527	8.527	5.560
T5 (10x20 cm)	11.95	81.80 a	32.24 b	251.6 cde	9.067	9.067	5.660
T6 (10x30 cm)	9.727	76.37 ab	33.90 ab	287.4 ab	8.420	8.420	5.780
T7 (15x10 cm)	11.77	64.66 c	27.63 cd	234.8 ef	8.663	8.663	5.683
T8 (15x20 cm)	10.50	73.75abc	32.59 b	272.3 bc	8.633	8.633	5.787
T9 (15x30 cm)	11.50	82.05 a	37.61 a	307.8 a	8.857	8.857	5.857
LSD (*P*=0.05)	3.952	10.62	4.478	22.63	1.486	1.486	0.60

Any two means in a column not sharing a letter differ significantly at 5 % probability level.

The maximum plant height (82.05 cm) was observed by the plants in T9 (15 x 30 cm), which was statistically at par with T1 (5x10 cm), T5 (10 x 20 cm) and T6 (10 x 30 cm). The minimum plant height (64.66 cm) was observed for T7 (15 x 10 cm), which did not differ significantly from T2 (5 x 20 cm) and T4 (10 x 10 cm). Linseed plants planted at 45 cm row spacing attained the maximum plant height of 88.35 cm (Khan *et al*., 2005). Whereas, Vender *et al.* (1995) and Singh (2001) reported that increased plant height at wider row spacing may be due to the availability of more space and solar radiation.

Seed capsule ratio, biological yield (kg ha^{-1}), seed yield (kg ha^{-1}) harvest index, fresh weight of weeds (kg m^{-2}) are presented in the *Table 3*. The maximum number of basal branches per plant (6.567) was produced by the crop grown at T9 (15 x 30 cm), which were statistically at par with T6 (10 x 30 cm), T8 (15 x 20 cm) and T3 (5 x 30 cm), whereas the minimum number of basal branches (2.14) were produced by T1 (5 x 10 cm). Leitch and Sahi (1999) reported that a better survival percentage of basal branches at lower densities. The maximum number of fruit bearing branches per plant (37.61) was produced by T9 (15 x 30 cm), which was statistically at par with T6 (10 x 30 cm). Whereas, the minimum fruit bearing branches per plant (23.54) was observed in T1 (5 x 10). More fruit-bearing branches at low densities so wider spacing produced more number of fruit-bearing branches per plant Bazzaz and Harper (1977). The maximum number of fruit bearing branches per plant (307.8) was produced by T9 (15 x 30 cm), which was statistically at par with T6 (10 x 30 cm). Whereas, the minimum fruit bearing branches per plant (225.8) was observed in T1 (5 x 10). The results are in line with the observations of Kurt (1996), that in 30 cm spacing competition for space resulted in reduction of number of capsules per plant, as compared to 45 cm row spacing. Similarly, Khan *et al.* (2005) make observations that number of capsules $plant^{-1}$ was affected significantly by different genotypes, row spacing and their interaction. The number of seeds per capsule has real participation for the seed yield, as they contribute materially towards the final yield of Linola. Above results are in line with the findings of Khan *et al.* (2005), who reported non-significant impact of row spacings on number of seeds per capsule. The maximum seed capsule ratio (1.450) was recorded for T9 (15 x 30 cm), which was statistically at par with T7 (15 x10 cm). Whereas, the minimum seed capsule ratio (1.390) was observed in T6 (10 x 30 cm). The maximum value for biological yield (4058.43) was observed for T8 (15 x 20 cm), which was at par with T9 (15 x 30 cm). The minimum value (3422.3) for biological yield was observed for T2 (5 x 20 cm). These results are in accordance with Pandey *et al.* (2002), who reported that higher biological yield at wider spacing may be due to the less competition as well as genetic make of the genotype. The maximum seed yield (1104.05 kg ha^{-1}) was observed for T8 (15 x 20 cm), which was at par with T6 (10 x 30 cm), T5 (10 x 20 cm) and T7 (15 x 10 cm). The minimum value for seed yield (917.2 kg ha^{-1}) was observed for T2 (5 x 20 cm), which did not differ significantly from T3 (5 x 30 cm) and T4 (10 x 10 cm). Khare *et al.* (1996)

observed higher yield with 30 cm row spacing. Similarly, Khan *et al.* (2005) concluded that seed yield was affected significantly by row spacing, genotypes and their interaction. Rennebaum *et al.* (2002) also stated that optimum plant population is very important yield component in field crops. The maximum harvest index value (29.09 %) was observed for T5 (10 x 20 cm) and was at par with T1 (5 x 10 cm), T2 (5 x 20 cm), T3 (5 x 30 cm), T6 (10 x 30 cm), T7 (15 x 10 cm) and T8 (15 x 20 cm). The minimum harvest index value (26.09%) was observed in T9 (15 x 30 cm). Our results are up to some extent correlated with Diepenbrock and Porksen (1992) statement that the highest harvest index (46.96 %), in case of linseed crop, was attained with the lowest plant population. The maximum weeds fresh weight (2.013) was observed for T9 (15 x 30 cm) and T6 (10 x 30 cm), those were statistically at par with T8 (15 x 20 cm), but statistically differed from the rest of the treatments. The minimum fresh weight of weeds (0.98) was produced by T1 (5 x 10 cm) and T2 (5 x 20 cm). Our results are in accordance to Paulsen *et al.* (2006), who made observations that in mixed cropping systems with linseed and false flax the soil covering were efficiently increased, compared to the sole cropping of linseed and was comparable to sole cropped false flax.

Table 3 - Seed capsule ratio, biological yield (kg ha^{-1}), seed yield (kg ha^{-1}) harvest index, fresh weight of weeds (kg m^{-2}) are affected by plant to plant and row to row spacing

Treatments	Seed capsule ratio	Biological yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)	Fresh weight of weeds (kg m^{-2})
T1(5x 10 cm)	1.410 ab	3467.37 e	1005 bc	29.05 a	0.9800 e
T2(5x20 cm)	1.427 ab	3422.30 e	917.2 d	26.83 ab	1.003 e
T3(5x30 cm)	1.440 ab	3494.48 e	972.3 cd	27.83 ab	1.293 d
T4(10x10 cm)	1.443 ab	3624.12 cde	964.6 cd	26.61 b	1.177 de
T5(10x20 cm)	1.423 ab	3585.57 de	1041 abc	29.09 a	1.357 d
T6(10x30 cm)	1.390 b	3836.83 abc	1086 ab	28.29 ab	1.913 ab
T7(15x10 cm)	1.447 a	3775.46 bcd	1066 ab	28.24 ab	1.577 c
T8(15x20 cm)	1.407 ab	4058.43 a	1104 a	27.21 ab	1.740 bc
T9(15x30 cm)	1.450 a	3960.96 ab	1034 abc	26.09 b	2.013 a
LSD (*P*=0.05)	0.054	230.5	85.53	2.268	0.2189

Any two means in a column not sharing a letter differ significantly at 5 % probability level.

Linoleic acid concentration (%), α linolenic acid concentration (%), stearic acid concentration, oleic acid concentration (%), oil concentration (%), palmitic acid concentration (%) are discuss in the *Table 4*. The maximum oil seed concentration (42.95 %) was observed for T9 (15 x 30 cm), which was statistically at par with all other treatments except T1

(5 x 10 cm), which produced the minimum oil concentration. Sher *et al.* (2001) discussed that planting pattern of 60/30 cm apart paired rows gave statistically highest oil contents in seed than all other planting pattern in *Brassica napus*. The T9 (15 x 30 cm) accumulated the maximum palmitic acid (7.510 %), which was statistically at par with T8 (15 x 20 cm) and T6 (10 x 30 cm), but differed significantly from rest of the treatments. The minimum palmitic acid (7.240 %) was observed in T1 (5 x 10 cm) and did not differ significantly from T2 (5 x 20 cm), T3 (5 x 30 cm) and T4 (10 x 10 cm). Cheema *et al.* (2001), who concluded that palmitic acid content increased significantly with increase in row spacing in *Brassica napus*.

Table 4 - Linoleic acid concentration (%), α linolenic acid concentration (%), stearic acid concentration, oleic acid concentration (%), oil concentration (%), palmitic acid concentration (%) are affected by row to row and plant to plant spacing.

Treatments	LAC (%)	α LAC (%)	SAC (%)	OAC (%)	OC (%)	PAC (%)
T1(5x 10 cm)	65.82 c	1.55 b	6.95 e	16.92 c	41.25 b	7.240 d
T2(5x 20 cm)	66.34bc	1.66 ab	7.20 de	17.26 abc	41.57 ab	7.293 cd
T3(5x 30 cm)	66.86 ab	1.77 ab	7.35 cd	17.42 abc	41.89 ab	7.333 cd
T4(10x10 cm)	66.46 abc	1.66 ab	7.00 e	17.19 bc	41.54 ab	7.283 cd
T5(10x20 cm)	67.22 abc	1.91 ab	7.51 bc	17.67 abc	42.36 ab	7.390 bc
T6(10x30 cm)	67.55 ab	2.42 ab	7.65 abc	18.09 ab	41.77 ab	7.473 ab
T7(15x10 cm)	66.68 abc	1.76 ab	7.42 bc	17.27 abc	42.78 a	7.353 c
T8(15x20 cm)	67.61 ab	2.44 ab	7.69 ab	18.10 ab	42.80 a	7.470 ab
T9(15x30 cm)	67.93 a	2.54 a	7.85 a	18.29 a	42.95 a	7.510 a
LSD (*P*=0.05)	1.574	0.9730	0.3096	1.097	1.438	0.1095

Any two means in a column not sharing a letter differ significantly at 5 % probability level.

The maximum stearic acid value (7.849%) was observed for T9 (15 x 30 cm), which was statistically at par with T8 (15 x 20 cm) and T6 (10 x 30 cm) and differed significantly from rest of the treatments. Whereas, the minimum stearic acid (6.945 %) was observed for T1 (5 x 10 cm), which was statistically at par with T2 (5 x 20 cm) and T4 (10 x 10 cm). Our results are different from those of Cheema *et al.* (2001), who concluded that stearic acid content decreased significantly with increase in row spacing in *Brassica napus*. The maximum oleic acid value (18.291 %) was observed at T9 (15 x 30 cm), which was statistically at par with T2, T3, T5, T6, T7 and T8. The minimum oleic acid value (16.921 %) was observed for T1 (5 x 10 cm). Higher oleic acid percentage may be due to higher temperature during the seed setting period. These results are in agreement with those of Cheema *et al.* (2001), who reported that the different row spacings affected significantly oleic acid contents in *Brassica napus*. The maximum linoleic acid value (67.93 %) was observed for T9 (15 x 30 cm), which was statistically at par with all other treatments, except T1 and T2. Whereas, the minimum linoleic acid value (65.82 %) was observed for T1 (5 x 10 cm). Cheema *et al.* (2001) reported that linoleic acid contents increased with an increase in row spacing in *Brassica napus*. The maximum α-linolenic acid value (2.536 %) was observed at T9 (15 x 30 cm), which was statistically at par with all other treatments, except T1, which produced the minimum (1.552 %) α-linolenic acid. These differences may be attributed to the prevailing temperature at physiological maturity stage. Contents of α-linolenic acid increased with the increase in plant to plant and row to row spacings.

CONCLUSION

It is revealed from the results that an increase in row and plant spacings resulted in non-consistent increases in the number of seeds per capsule. Higher plant populations contributed to the control of the growth and development of weeds both. Seed yield increased with increasing the row to row and plant to plant sapcings. The results of this study suggested that seed yield was significantly affected by row to row and plant to plant spacings and Linola yield were lower at the narrow (10 × 10 cm) row and plant spacings, compared to the wider (15 × 30 cm) spacings. Thus, it is concluded that Linola should be grown at 300-450 cm grids by farmers for higher yield output in the field at rainfed conditions.

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