

Research Article

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Interspecific crosses of linseed species

Renjini J. S.^{1*}, Beena Nair² and Rani Jadhav²¹Department of Genetics and Plant Breeding, College of Agriculture, Nagpur, India²AICRP on Linseed and Mustard, College of Agriculture, Nagpur, India

(Dr. Panjabrao Deshmukh Krushi Vidyapeeth, Akola, MH-440001, India)

**ABSTRACT**

Nine interspecific crosses obtained from crossing *L.usitatissimum* with two strains of *L. bienne* and seven strains of *L. grandiflorum* were studied in detail for various morphological characters like days to maturity, No. of branches plant⁻¹, pollen fertility (%), flower size (mm), seed color, 1000 seed weight (g), crossing efficiency (%), capsule set, cell size (μm), stomata size (μm), and growth habit. Interspecific hybrids were generally intermediate for certain morphological characters studied. However, some of them exhibited vigor for characters like days to maturity, plant height, cell size, etc. The results suggested that the F₁ cross-compatibility of interspecific crosses was specific to the parents involved in cross and showed a wide variation of success in hybridization percent. The seed formation in the F₁ plant was considerably reduced. the hybrids showed varying degrees of pollen and seed sterility despite their chromosome pairing and separating regularly.

Keywords: Interspecific, Crossing efficiency, Linseed, *L.bienne*, Pollen fertility

I. INTRODUCTION

Linseed or Flax is an annual, self-pollinating, autogamous diploid (2n=2x=30) oilseed crop, belonging to the family Linaceae having 14 genera and over 200 species [4]. A wide range of species diversity exists within the genus along with diverse basic chromosome numbers ranging from n = 8 to 43. [3] reported the occurrence of five wild spp. viz. *L.perenne*, *L.strictum*, *L.mysorensis*, *L.angustifolium*, *L.grandiflorum*. The species *L.usitatissimum* with 2n=30 chromosome is most extensively cultivated throughout the world, although there are reports of other 30 chromosome species under cultivation [10]. Several wild species of *Linum* possess many agronomically valuable genes such as resistance to disease and drought, winterhardiness, etc. [16] which may be of great value if transferred to the cultivated species. Studies on successful interspecific hybridization in this gene are limited and attempts by earlier workers have not been studied systematically. Hence, the present study was undertaken to obtain fertile hybrids and to compare them with their parents.

II. MATERIALS AND METHODS

Two strains of *L. Bienne* (EC-993391, EC-993389) and seven strains of *L.grandiflorum* [IC-633096, IC-633096 – yellow anther, IC-633096 (0.10 mg/L colchicine treated bud - black anther - 72 hrs), IC-633096 (0.15 mg/L colchicine treated bud - black anther - 72 hrs), IC-633096 (0.20 mg/L colchicine treated bud - black anther - 72 hrs), IC-633096 (0.05 mg/L colchicine treated bud - black anther - 72 hrs), IC-633096 (0.15 mg/L

colchicine treated shoot tip - black anther - 24 hrs)] were crossed with T-397 (*L.usitatissimum*) during rabi 2022. The F₁ crosses were grown along with the parents in non-replicated trial with the spacing 30 × 10 cm. The observations on successive hybridization were recorded during F₀ generation on characters like days to maturity, No. of branches plant⁻¹, pollen fertility (%), flower size (mm), seed colour, 1000 seed weight (g), crossing efficiency (%), capsule set, cell size (μm), stomata size (μm), and growth habit. The percentage success in hybridization was worked out by the formula (number of capsule set/number of pollination made) × 100.

III. RESULTS AND DISCUSSION

Nine interspecific crosses were made in the study and the number of pollinations made, number of capsule sets, average seed set capsule⁻¹ etc., in each cross were noted and presented in Table 1.

The success of setting in interspecific crosses ranged from 13.3% in cross T-397 × IC-633096 (0.20 mg/L) to 88.0% in cross T-397 × EC-993389 which was followed by T-397 × EC-993391 (85.4%), T-397 × IC-633096 (Y - 35.0%). [9] observed 73 % seed set in *B. juncea* × *B. napus* cross. Similarly, [6] also observed 92.1% seed set in cross TM-1 × N-5 (a cross between *B. juncea* × *B. napus*).

The average seed set capsule⁻¹ ranged from 2.0 (T-397 × IC-633096 - 0.15 mg/L – shoot tip) to 10.33 (T-397 × IC-633096 - 0.10 mg/L). The average number of seeds capsule⁻¹ for cultivated T-397 (*Linum usitatissimum*) ranged from 7 to 9, and may extend upto 10 to 12. However, the average number of seed set in one capsule is 3 to 4 in F₁ crosses, the highest being 10.33 in T-397 × IC-633096 (0.10 mg/L) followed by 6.2 in T-397 × IC-633096 (0.15 mg/L).

It was observed that the seed set in wide crosses were lesser than the normal seed setting of intervarietal crosses. There was wide variation for average seed set capsule⁻¹ which indicates the speciality of genotypes for compatibility.

*Corresponding Author: **Renjini J. S.**

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Table 1. Crossing efficiency in interspecific hybrids

Crosses	No. of pollination effected	No of Capsule set	Percent success in hybridization	Number of viable seeds	Average seed set capsule ⁻¹
T-397 × EC-993391	103	88	85.4	187	2.12
T-397 × EC-993389	50	44	88.0	89	2.03
T-397 × IC-633096	50	10	20.0	36	3.6
T-397 × IC-633096 (0.10 mg/L)	34	6	17.6	62	10.33
T-397 × IC-633096 (0.15 mg/L)	25	5	20.0	31	6.2
T-397 × IC-633096 (0.20 mg/L)	30	4	13.3	16	4.0
T-397 × IC-633096 (0.05 mg/L)	20	3	15.0	11	3.66
T-397 × IC-633096 (0.15 mg/L - shoot tip)	24	3	12.5	6	2.0
T-397 × IC-633096 (Y)	20	7	35.0	25	3.57

Germination percentage

The data on mean value of parents for germination percentage ranged from 4% to 94% (Table 2). The germination percentage was maximum for T-397 (94%) followed by IC-633096 (Y - 89.00%), IC-633096 (0.20 mg/L - 88.0%), while it was minimum in EC-993391 (4%) followed by EC-993389 (8%).

The germination percentage of F₁ ranged from 24.70% to 58.1% (Table 3). The germination percentage was maximum for T-397 × IC-633096 (0.15 mg/L - shoot tip - 58.1 %) followed by T-397 × IC-633096 (0.20 mg/L - 56.5%), while it was minimum in T-397 × IC-633096 (24.7%) followed by T-397 × IC-633096 (0.15 mg/L - 27.4%).

Pollen fertility

Though the pollen fertility was 100% for all the parents used in the crossing programme. Pollen fertility of F₁ ranged from 95.2% to 100% (Table 3). Maximum pollen fertility was observed in T-397 × EC-993391 and T-397 × EC-993389 (100%) followed by T-397 × IC-633096 (0.15 mg/L - 98.8%), while it was minimum for T-397 × IC-633096 (0.05 mg/L - 95.2%) followed by T-397 × IC-633096 (96.4%) and T-397 × IC-633096 (0.20 mg/L - 96.8%). Low pollen fertility in F₁ was due to incompatibilities between chromosomes of both parents involved in the crosses. [10] observed that F₁ hybrids showed reduced pollen fertility although meiosis was fairly normal in hybrids, so the reduced pollen fertility was due to genic imbalance.

The F₂ population size in each of the interspecific cross was considerably small because of very low fertility in interspecific F₁'s. The germination percentage of F₂ population ranged from 2.82 to 17.14%. The germination percentage was maximum for T-397 × IC-633096 (17.14) followed by T-397 × *L. grandiflorum* (4.78%), while it was minimum in T-397 × EC-993389 (2.82%) followed by T-397 × EC-993391 (4.38%).

Flower colour

The flower colour of all the F₁ plants of the crosses between blue flowered (*L.usitatissimum*) and red flowered (*L.grandiflorum*) was blue (Table 3), showing thereby the dominance of blue colour over the red. The inheritance of flower colour in intervarietal crosses of *L.usitatissimum* has been studied extensively by [14], [11], [1]. In all the studies the blue colour of the petals was found dominant over the other colour studied. The dominance of blue colour of flower has also been reported in interspecific crosses between *L.usitatissimum* and *L.africanum* by [2].

Days to maturity

The data on mean value for days to maturity of parents ranged from 90 to 95 days (Table 2). The genotype T-397 (90 days) followed by EC-993391, EC-993389 (91 days) matured earliest and the genotype IC-633096 (0.15 mg/L), IC-633096 (0.05 mg/L), IC-633096 (0.15 mg/L - shoot tip treated - 95 days) followed by IC-633096 (0.10 mg/L), IC-633096 (0.20 mg/L - 94 days) matured late.

The data on mean value for days to maturity of F₁ ranged from 89 to 93 (Table 3). The crosses T-397 × EC-993391, T-397 × EC-993389 (89 days) followed by T-397 × IC-633096, T-397 × IC-633096 (Y - 90 days) matured earliest while the crosses T-397 × IC-633096 (0.15 mg/L - 93 days) followed by T-397 × IC-633096 (0.05 mg/L - 92 days) matured late. [12] observed that days to maturity revealed a significant reduction in the progenies over the parents in mustard interspecific crosses.

Stomata size

The data on stomata size of parents ranged from 17.95 to 29.41 μm (Table 2). The stomata size was maximum in IC-633096 (0.15 mg/L - 29.14 μm) followed by IC-633096 (0.20 mg/L - 27.77 μm), while it was minimum in EC-993391 (17.95 μm) followed by EC-993389 (19.60 μm).

The data on stomata size of F₁ ranged from 13.5 to 29.7 (Table 3). The stomata size was maximum in T-397 × IC-633096 (0.10 mg/L - 29.7 μm) followed by T-397 × IC-633096 (Y - 24.4 μm), while it was minimum in T-397 × EC-993389 (13.5 μm) followed by T-397 × EC-993391 (15.8 μm). [7] reported similar results in mustard that the stomata size of parents was lower than their hybrids.

Cell size

The data on cell size of parents ranged from 34.38 to 76.38 μm (Table 2). The cell size was maximum for IC-633096 (0.10 mg/L - 76.38 μm) followed by IC-633096 (Y - 64.50 μm), while it was minimum in EC-993389 (34.38 μm) followed by EC-993391 (38.70 μm).

The data on cell size of F₁ ranged from 42.27 to 129.4 μm (Table 3). The cell size was maximum for T-397 × IC-633096 (0.15 mg/L - 129.4 μm) followed by T-397 × IC-633096 (90.7 μm), while it was minimum in T-397 × EC-993391 (42.27 μm) followed by T-397 × EC-993389 (60.10 μm).

Number of branches plant⁻¹

The data on number of branches plant⁻¹ of parents ranged from 3.80 to 5.40 (Table 2). The genotype IC-633096 (0.20 mg/L - 5.40) followed by T-397 (5.26) recorded maximum number of branches plant⁻¹, while least number of branches plant⁻¹ was for

IC-633096 (0.10 mg/L - 3.80) followed by IC-633096 (0.15 mg/L - 4.40). The results on number of branches plant⁻¹ of T-397 (*Linum usitatissimum*) was in accordance with the observations of [15].

The data on number of branches plant⁻¹ of F₁ ranged from 4.20 to 5.40 (Table 3). The cross T-397 × EC-993391 (5.40) followed by T-397 × IC-633096 (0.15 mg/L - shoot tip - 5.30) recorded maximum number of branches plant⁻¹, while least number of branches plant⁻¹ was for T-397 × IC-633096 (0.05 mg/L - 4.20) followed by T-397 × IC-633096 (0.15 mg/L - 4.40). [6] also put forward same conclusion in Mustard interspecific crosses that wide range of variation was observed among crosses for the character number of branches plant⁻¹.

Plant height

The data on mean value for plant height at maturity of parents ranged from 24.0 cm to 34.98 cm (Table 2). The genotype EC-993389 (24.0 cm) was shortest followed by EC-993391 (27.20 cm) and genotype IC-633096 (34.98 cm) was tallest followed by IC-633096 (Y - 32.96 cm). The results on plant height of T-397 (*Linum usitatissimum*) was in accordance with the observations of [15]. The data on mean value for plant height at maturity of F₁ ranged from 23.84 cm to 36.42 cm (Table 3). The cross T-397 × EC-993391 (23.84 cm) was shortest followed by T-397 × IC-633096 (0.10 mg/L - 29.30 cm) and the cross T-397 × IC-633096 (Y - 36.42 cm) was tallest followed T-397 × IC-633096 (0.20 mg/L - 32.52 cm).

Flower size

The data on mean value for flower size of parents ranged 13.3 to 23.80 mm (Table 2). The flower size was maximum for IC-633096 (0.20 mg/L - 23.80 mm) followed by IC-633096 (Y - 22.2 mm), while it was minimum for EC-993391 (13.3 mm) followed by EC-993389 (13.45 mm). The results on flower size of T-397 (*Linum usitatissimum*) was in accordance with the observations of [15].

The data on mean values for flower size of F₁ ranged from 13.60 to 16.55 mm (Table 3). T-397 × EC-993391 (16.55 mm) followed by T-397 × IC-633096 (0.20 mg/L - 16.40 mm) possessed maximum flower size, T-397 × EC-993389 (13.60 mm) followed by T-397 × IC-633096 (0.15 mg/L - 72 hrs - 15.20 mm) showed minimum flower size.

Growth habit

Parent T-397 had semi erect growth habit, EC-993391 and EC-993389 had bushy growth habit, IC-633096 (control and treated) had erect growth habit, F₁ obtained from cross with EC-993391 and EC-993389 had all bushy habit and F₁ obtained from cross with IC-633096 (control and treated) had semi erect habit. [5] concluded from the studies conducted in 34 linseed genotypes 7 (21%) linseed varieties exhibited erect whereas 10 (29%) genotypes had semi-erect type of growth habit and rest of 17 (35%) genotypes were having spreading type of growth habit indicating the dominance of spreading type habit.

1000-seed weight

The data on 1000-seed weight of parents ranged from 4.0 to 7.5 g (Table 2). The 1000-seed weight was maximum in T-397 (7.5 g) followed by IC-633096 (6.7 g), while it was minimum in EC-993389 (4.0 g) followed by EC-993391 (4.2 g).

The data on 1000-seed weight of parents F₁ ranged from 5.41 to 6.36 g (Table 3). The 1000 seed weight was maximum in T-397 × IC-633096 (0.05 mg/L - 6.36 g) followed by T-397 × IC-633096

(0.10 mg/L - 6.31 g), while it was minimum in T-397 × EC-993389 (5.41 g) followed by T-397 × EC-993391 (5.50 g).

Seed colour

The parent T-397 had dark brown seed colour, parents EC-993391 and EC-993389 had brown seed colour and all IC-633096 (control and treated) had fawn seed colour, while all F₁ had dark brown seed colour. [14] and [11] have reported that brown seed colour was governed by three dominant genes.



T-397 EC-993389



T-397 × EC-993389 Stomata size of T-397 × EC-993389

Plate 1. T-397 × EC-993389 (F₁) and their parents along with stomata size of T-397 × EC-993389

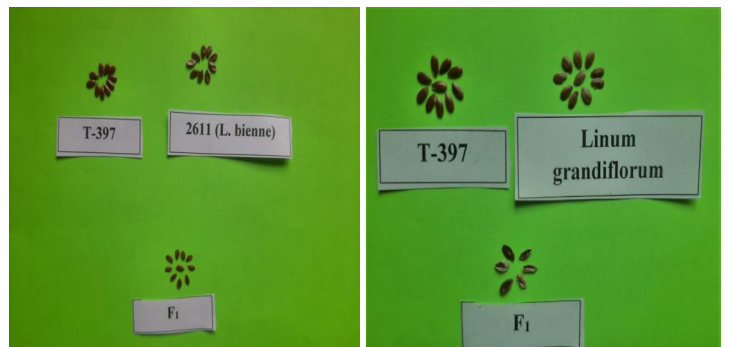


Plate 2. Seed size of T-397 × EC-993389 and T-397 × L. grandiflorum

Table 2. Mean performance of parents for various morphological characters

Character	T-397	EC-993391	EC-993389	IC-633096	IC-633096 (0.10 mg/L)	IC-633096 (0.15 mg/L)	IC-633096 (0.20mg/L)	IC-633096 (0.05mg/L)	IC-633096 (0.15 mg/L - shoot tip)	IC-633096 - yellow anther
Days to maturity	90	91	91	93	94	95	94	95	95	94
No. of branches plant ⁻¹	5.26	4.45	5.20	4.60	3.80	4.40	5.40	5.00	4.80	5.20
Pollen fertility	100	100	100	100	100	100	100	100	100	100
Growth habit	Semi erect habit	Bushy habit	Bushy habit	Erect habit	Erect habit	Erect habit	Erect habit	Erect habit	Erect habit	Erect habit
Flower size	15.98	13.30	13.45	22.20	20.12	21.20	23.80	20.67	21.87	22.22
Seed colour	Dark brown	Brown	Brown	Fawn	Fawn	Fawn	Fawn	Fawn	Fawn	Fawn
1000 seed weight (g)	7.5	4.2	4.0	6.7	6.4	5.5	5.9	6.0	6.2	5.6
Germination percentage	94.00	4.00	8.00	86.00	85.00	82.00	88.00	85.00	87.00	89.00
Plant height	29.84	27.20	24.00	34.98	31.20	32.52	31.00	31.32	32.11	32.96
Cell size (µm)	57.52	38.70	34.38	62.95	76.38	58.31	60.10	57.45	58.33	64.50
Stomata size (µm)	25.34	17.95	19.60	26.80	27.33	29.14	27.77	26.54	25.13	27.23
Flower colour	Blue	Blue	Blue	Red	Red	Red	Red	Red	Red	Red

Table 3. Mean performance of F1 for various morphological characters.

Character	T-397 × EC-993391	T-397 × EC-993389	T-397 × IC-633096	T-397 × IC-633096 (0.10 mg/L)	T-397 × IC-633096 (0.15 mg/L)	T-397 × IC-633096 (0.20 mg/L)	T-397 × IC-633096 (0.05mg/L)	T-397 × IC-633096 (0.15 mg/L - shoot tip)	T-397 × IC-633096 (Y)
Days to maturity	89	89	90	91	93	91	92	91	90
No. of branches plant ⁻¹	5.40	5.00	4.50	4.80	4.40	5.20	4.20	5.30	4.60
Pollen fertility	100	100	96.4	98.5	98.8	96.6	95.2	98.6	98.2
Growth habit	Bushy habit	Bushy habit	semi erect habit	semi erect habit	semi erect habit	semi erect habit	semi erect habit	semi erect habit	semi erect habit
Flower size	16.55	13.60	15.36	15.34	15.20	16.40	15.84	15.74	15.94
Seed colour	dark brown	dark brown	dark brown	dark brown	dark brown	dark brown	dark brown	dark brown	dark brown
1000 seed weight (g)	5.50	5.41	6.17	6.31	5.76	5.90	6.36	6.12	5.81
Germination percentage	50.1	32.4	24.7	56.6	27.4	56.5	50.6	58.1	41.8
Plant height	23.84	30.78	30.00	29.30	31.20	32.52	31.00	31.32	36.42
Cell size (µm)	42.27	60.10	90.7	79.3	129.4	76.6	62.1	74.8	63.2
Stomata size (µm)	15.8	13.5	21.6	29.7	18.1	18.3	13.8	14.9	24.4
Flower colour	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue

IV. CONCLUSION

Interspecific hybridization is one of the most promising and at the same time frustrating tools available to the plant breeder [13]. [8] attempted interspecific hybridization between 10 species and only hybridization between *L.usitatissimum* and *L.angustifolium* was successful.

In the present study, Nine interspecific crosses were studied in detail for various morphological characters. Considerable diversity was observed between different species for different morphological characters like Days to maturity, No. of branches plant⁻¹, Pollen fertility, Growth habit, Flower size, seed color, 1000 seed weight (g), Germination percentage, plant height, cell size, stomata size. Interspecific hybrids were generally intermediate for certain morphological characters studied. However, some of them exhibited hybrid vigor for characters like days to maturity, plant height, cell size etc. All hybrids except cross with *L.bienni* expressed partial pollen sterility, which was reflected in reduced seed fertility. [10] concluded a similar result that all the hybrids expressed partial pollen sterility. Attempts made to cross the species with varying chromosome numbers with the cultivated species showed success. It may be possible by embryo culture to overcome this difficulty and secure fertile hybrids which may be useful not only in transferring some of its useful genes into the cultivated species but also in establishing inter-relationships [10].

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