Seed Res., Vol. 42(1): 38-46 June 2014

Effect of seed enhancement treatments on field emergence, flowering behaviour and seed yield of speciality maize

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ABSTRACT Efficacy of pre-sowing seed enhancement treatments namely hydro, matrix (Pusa hydrogel), halo (KNO_3@ 0.3%), bio-priming (fulvic acid @ 0.1% and earth worm-derived compounds: ceolomic fluid, vermiwash), seed treatments (Thiram @ 3 g/kg of seed, Cruiser @ 4g/kg of seed and Kalisena @ 8g/kg of seed), and magnetic stimulation (1000 G for 2h) singly or in combination were assessed on speciality maize *i.e.* Quality protein maize 'HQPM-1', Pop corn 'VL Amber pop corn', Sweet corn 'Win orange sweet corn' and common maize 'Parkash'. The results showed significant beneficial effect of seed enhancement treatments on field emergence, speed of emergence, early seedling growth (fresh and dry weight), plant height and seed yield. These treatments advanced flowering by 1-2 days over control. Hydro-priming (17h for 20°C) followed by dry dressing with thiram (3g/kg of seed), halo-priming with KNO_3 (0.3%) (17h for 20°C), bio-priming with fulvic acid (0.1%) and ceolomic fluid and magnetic stimulation (1000 G for 2h) were more effective in improving field performance and yield of genotypes as compared to control. Among cultivars, Win orange sweet corn and Parkash were more responsive to seed enhancement treatments than HQPM-1 and VL Amber popcorn.

Keywords: Maize, pre-sowing seed treatment, seed enhancement, field emergence, flowering, seed yield

Rapid and uniform field emergence is critical for optimization of stand establishment in maize under all environmental conditions, but physiological constraints along with abiotic and biotic stresses result in poor germination and crop stand. Seed enhancement treatments are widely adopted for improved performance, in terms of seed germination, stand establishment, early seedling growth, flowering and yield. The seed enhancement treatments namely seed priming, seed treatment with chemicals (both in-organic and organic), seed coating and exposure to physical treatments like magnetic stimulation are commonly used in maize. Beneficial effect of seed priming treatments on seed germination, seedling establishment and crop stand has been well documented [1-3]. Parrera and Cantliffe [4] reported that solid matrix priming and hydro-priming improved early seedling vigour and vegetative growth in sweet corn. Pre-sowing hydro-priming followed by dry dressing with Thiram, osmo (PEG) and halo (KNO_3) priming improved field emergence and crop stand in maize [5]. Seed enhancement with Kalisena (*Aspergillus niger*) and earthworm derived products (ceolomic fluid, vermiwash, nurtiwash) are reported to enhance seed germination, speed of emergence, root and shoot length, early vegetative growth, flowering in maize, onion and chickpea [6-8]. Exposure of maize and chickpea seeds to static magnetic field improved seed germination, speed of germination, seedling length, dry weight and root length [9-10]. Beneficial effect of seed enhancement treatments on flowering [5, 11] and yield [12] has also been reported in maize. Chemical composition of a seed influences not only its quality, but also its response to different seed enhancement treatments. Maize genotypes are available in different quality groups *viz.*, sweet corn (high sugar content), popcorn, quality protein maize (high lysine and tryptophan), *vis-à-vis* common maize, which vary in their genetic and chemical composition. No information is available on the response of maize genotypes to seed

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Received: December 2013 Revised: June 2014 Accepted: June 2014

enhancement treatments belonging to different chemical compositional groups. Thus, the present study was undertaken to elucidate the effect of seed enhancement treatments on field performance and yield of maize varieties belonging to different quality groups.

MATERIALS AND METHODS

Seeds of speciality maize varieties *i.e.*, HQPM-1(quality protein maize, single cross), VL Amber pop corn (pop corn, composite), Win orange sweet corn (sweet corn, composite)] and Parkash (common maize, composite) obtained from the Directorate of Maize Research (DMR), New Delhi; VPKAS, Almora; DMR, Winter Nursery, Hyderabad and DMR, New Delhi, respectively were used for the study. The initial germination was 95, 98, 85 and 88%, respectively, whereas, seed moisture varied from 8-9%. Seeds were subjected to pre-sowing seed enhancement treatments; hydro-priming (T_2), hydro-priming followed by dry dressing with thiram (3g/kg of seed) (T_3), matrix priming with Pusa hydro-gel (T_4), halo-priming (KNO_3: 0.3%) (T_5), priming with fulvic acid: 0.1 % (T_6), dry dressing with pesticides, cruiser (4ml / kg of seed) (T_7), thiram (3g/kg of seed) (T_8), biofungicide (Kalisena*: 8 g / kg of seed) (T_9); priming with earth worm-derived compounds [ceolomic fluid** (T_{10}) and vermiwash*** (T_{11})], and low temperature hydro-priming (72h for 10^0C) (T_{13}). All the treatments were given for 17hr at 20^0C except T_{13}. (**Aspergillus niger* powder, a biofungicide developed by ICAR-Indian Agricultural Research Institute, New Delhi; **Coelomic fluid of earthworm; ***Washing of earthworm)

Seeds of above genotypes were subjected to hydro, halo and bio-priming by keeping the seeds on soaked filter paper hydrated with distilled water, KNO_3 (0.3%), fulvic acid (0.1 %) and earth worm-derived compounds (ceolomic fluid and vermiwash), respectively in Petri dishes for 17h at 20^0C. For matrix priming, seeds were mixed with hydrogel (1g gel in 200 ml water) in 3:1 ratio (V/V). The hydrated seeds were air dried under ambient temperature.

For magnetic stimulation treatment (T_{12}), 100 seeds were placed in a cylindrical sample holder of 42 cm^3 capacity. The sample holder was placed in between the poles of an electromagnet having uniform magnetic field. The seeds were exposed to 1000 G for 2h. The untreated seeds were taken as control (T_1).

Efficacy of seed enhancement treatments on field emergence, rate and uniformity of emergence, vegetative growth, days to flowering (anthesis and silking) and yield was evaluated under Delhi conditions during *Kharif* 2009. The temperature, always expand first time and total rainfall during crop growth ranged from 34.9-18.7^{0}C, 91.4- 41.8 percent and 179.9 mm, respectively. The experiment was laid in split plot design with three replications. Plot size was 5 m x 3 m with row-to-row spacing and plant-to-plant spacing of 75 cm and 25 cm, respectively. Genotypes were put in the main plot and treatments in the sub plot. Field emergence percentage was recorded on 14 days from sowing.

$$\text{Percentage emergence} = \frac{\text{Number of seedlings in four rows}}{\text{*Total number of seeds sown in four rows per replications}} \times 100$$

Speed of emergence was computed as per the formula $\Sigma n/t$ [13].

Where, n is number of seeds newly germinated at time t and t is days from seed sowing.

After taking the final count on field emergence, five seedlings from each replication were weighed followed by drying at $80^0 \pm 1^0$C for 24h for seedling fresh and dry weight. Plant height was recorded from the base to the tip of the tassel after completion of flowering in ten randomly selected plants per replication. Days to first anthesis and first silking was recorded as day of opening of first spikelet in a tassel and first silk in the cob, respectively in the plot. Number of days to 50 percent anthesis and 50 percent silking was recorded, when the tassel started flowering and silk emerged, respectively in 50 percent of the plants in the plot. At field maturity (18% moisture content), total cobs from each plot were selected, harvested, hand threshed and seed yield per plot was calculated and expressed as kg per plot. Hundred seeds from each treatment were counted and weighed to record test weight (g).

RESULTS AND DISCUSSION

Field emergence and early vegetative growth

Environmental conditions control all growth stages of crop but seedling emergence, establishment and early vegetative growth are more influenced than later growth stages. In the present investigation, seed enhancement treatments significantly improved field emergence and speed of emergence by 2.33-15.61% and 19.61–37.75%, respectively compared with control (Table 1). Among treatments, hydro-priming (with or without fungicide), halo-priming (KNO_3), priming with ceolomic fluid and magnetic treatment were most effective in improving above traits as compared to control. The analysis of variance showed that these treatments significantly increased early vegetative growth expressed as seedling fresh and dry weight, which increased by18.57-20.72% and 2.70-3.78%, respectively over control in treated plots (Table 2). Beneficial effects of these treatments persisted throughout the crop growth but tapered in later growth stages. The plant height at late flowering stage was significantly higher in treated plots (7.18 to 20.72%) as compared to control (Table 2). Similar improvements in field emergence, its speed, stand establishment and early vegetative growth under field conditions by seed enhancement treatments had been reported [14-17].

Effect of seed enhancement treatments were expressed as early field emergence, uniform stand and vigorous crop growth in the plots sown with treated seeds. This could be attributed to early activation of metabolic activities during seed enhancement, which resulted in early germination, emergence, improved seedling and root growth and early vegetative growth. Thus, seed enhancement treatments provided better stand assurance and sustainability under adverse conditions of abiotic stresses like varied temperature and soil moisture regimes.

Flowering behaviour

Flowering time is critical for higher seed yield. In the study, initiation of flowering (days to first anthesis and silking) was earlier in plots sown with treated seeds. Fifty percent anthesis and silking in treated plots was advanced by 1-2 days as compared to control (Table 3). Anthesis silking interval *i.e.* difference in days to anthesis in tassel and silking in cob was also reduced by 1-2 days, suggesting the possibility of employing these treatments for manipulation of flowering behaviour and synchronization of flowering in parental lines in hybrid combinations, where the gap in flowering ranges between 2-3 days. It was reported that, hydro-priming of late parent in a hybrid combination advanced flowering by 4-5 days resulting in synchronization of flowering among parental lines during hybrid seed production of Sartaj, a single cross hybrid [11]. Pre-sowing seed hydration treatments induced early flowering in maize [5, 12].

Seed yield

Differential response to seed enhancement treatments is well-known and effect of these treatments is more pronounced in species harvested at early vegetative state and diminishes in crops harvested at late maturity

Table 1. Effect of seed enhancement treatments on field emergence and speed of emergence in maize genotypes.

	Field emergence (%) treatments													
Variety	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	Mean
P_1	87.4	90.7	91.1	89.5	89.3	90.0	89.2	86.4	83.1	84.5	81.4	92.9	84.3	87.7
	(69.7)	(72.9)	(74.0)	(71.2)	(71.8)	(71.6)	(71.0)	(69.1)	(66.6)	(67.1)	(64.6)	(74.8)	(97.1)	(70.1)
P_2	81.9	89.8	90.0	76.2	89.8	92.6	87.6	86.2	87.6	89.0	87.1	91.2	89.7	87.4
	(64.9)	(71.6)	(71.7)	(61.0)	(71.4)	(74.7)	(69.5)	(68.3)	(69.4)	(70.8)	(69.1)	(73.2)	(68.7)	(69.6)
P_3	52.1	59.5	59.8	53.3	55.7	59.5	65.5	62.6	55.1	62.1	54.3	58.1	46.7	57.3
	(46.2)	(50.5)	(50.7)	(46.9)	(48.3)	(53.8)	(54.0)	(52.4)	(47.9)	(52.0)	(47.5)	(49.7)	(43.1)	(49.5)
P_4	52.9	70.7	70.5	68.1	66.4	75.0	69.0	66.4	61.2	62.1	57.9	62.9	53.6	64.4
	(46.6)	(57.3)	(57.3)	(55.6)	(54.6)	(60.2)	(56.6)	(54.7)	(51.5)	(52.1)	(49.5)	(52.5)	(47.0)	(53.5)
Mean	68.6	77.7	77.9	71.8	75.3	79.3	77.9	75.4	71.9	74.5	70.2	76.2	67.8	
	(56.7)	(63.1)	(63.4)	(58.7)	(61.5)	(65.1)	(62.8)	(61.1)	(58.8)	(60.5)	(57.7)	(62.5)	(56.5)	
%gain over control	-	13.3	13.5	4.6	9.8	15.6	13.6	9.9	4.8	8.6	2.3	11.0	-1.1	
CD (0.05)	Variety (V)	2.60		Treatment (T)		3.21				Interaction	V	NS	T	NS
SEM (±)		0.567				1.16						2.04		2.31

Speed of emergence

	Treatment													
Variety	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	Mean
P_1	16.8	20.9	21.2	20.1	22.0	21.1	20.1	19.98	19.4	20.4	21.3	21.4	20.9	20.5
P_2	15.1	19.8	20.7	19.3	19.2	18.8	18.4	18.13	18.2	19.3	20.2	19.0	18.1	18.8
P_3	10.9	12.3	12.9	11.1	12.2	15.5	13.0	13.23	10.3	12.2	12.0	10.9	11.6	12.2
P_4	8.8	14.0	13.7	13.8	13.4	15.5	13.0	12.53	11.9	14.9	14.6	11.4	10.9	12.9
Mean	12.9	16.8	17.1	16.1	16.7	17.8	16.3	15.9	14.9	16.8	17.0	15.7	15.4	
%gain over control	-	30.2	32.5	24.8	29.4	37.7	26.4	23.3	15.5	30.2	31.8	21.7	19.4	
CD (0.05)														
SEM (±)	Variety (V)		2.71			Treatment (T)	1.21		Interaction	V	NS	T	NS	
			0.783				0.462				2.82		1.00	

*Figures in parenthesis are the arc sine transformed values

P_1 = HQPM-1, P_2 = VL Amber pop corn, P_3 = Win orange sweet corn and P_4 = Parkash

T_1 = Control, T_2 = Hydropriming, T_3 = Hydropriming + Thiram (3g/kg of seed), T_4 = Matrix priming with hydrogel, T_5 = Halopriming (KNO_3: 0.3 %), T_6 = Priming with fulvic acid : 0.1 %, T_7 = Cruiser : 4 ml / kg of seed, T_8 = Thiram: 3g/ kg of seed, T_9 = Kalisena : 8g/ kg of seed, T_{10} = Priming with ceolomic fluid, T_{11} = Priming with vermiwash, T_{12} = Magnetic stimulation (1000 G/ 2h) , T_{13} = Low temperature hydration (72h / 10 °C) .

Table 2. Effect of seed enhancement treatments on seedling weight and plant height in maize genotypes

	Treatment													
Seedling fresh weight (g)														
Variety	T_1	T_2	T_3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	Mean
P1	16.47	19.1	20.11	17.58	19.47	20.39	19.92	17.36	12.89	17.20	14.40	16.33	19.86	17.78
P2	7.70	7.86	7.07	8.99	8.92	7.56	8.78	7.60	8.18	9.88	9.33	9.65	7.19	8.36
P3	6.62	8.65	7.83	9.50	8.74	7.94	7.82	7.12	7.17	7.90	7.59	7.54	6.69	7.78
P4	7.99	9.38	11.83	9.15	8.31	10.77	8.71	7.41	12.53	9.15	6.42	8.50	7.75	9.09
Mean	9.69	11.24	11.71	11.39	11.36	11.66	11.30	9.87	10.19	11.03	9.44	10.51	10.37	
CD (0.05)	Variety (V)		1.91		Treatment (T)	1.16		Interaction	V	2.88	T	1.70		
SEM (±)			0.783				0.462					2.82		1.00
Seedling dry weight (g)														
Variety	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	Mean
P1	2.14	2.77	2.54	2.18	2.42	2.82	2.49	2.29	1.75	2.60	2.21	2.83	2.23	2.40
P2	1.20	1.64	1.75	1.37	1.56	1.78	1.58	1.10	1.17	1.59	1.39	1.72	1.46	1.48
P3	1.33	1.58	1.47	1.5	1.66	1.40	1.14	1.20	1.14	1.59	1.39	1.61	1.25	1.40
P4	1.27	1.66	1.69	1.75	1.73	1.93	1.24	1.20	1.85	1.79	1.65	1.68	1.16	1.58
Mean	1.48	1.91	1.86	1.70	1.84	1.98	1.61	1.44	1.48	1.89	1.66	1.96	1.52	
CD (0.05)	Variety (V)		0.167		Treatment (T)		0.184	Interaction	V	0.447	T	0.462		
SEM (±)				0.059				0.077				0.213		0.101
Plant height (cm)														
Variety	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	Mean
P1	267.8	292.8	313.8	239.0	308.1	307.1	303.4	266.9	198.2	287.7	225.0	288.0	296.5	276.4
P2	134.4	153.1	147.4	143.9	150.6	155.3	186.2	120.3	127.6	153.9	162.6	158.5	134.4	148.3
P3	111.7	124.3	125.2	134.8	131.1	126.8	127.4	114.3	114.4	127.5	122.5	127.6	111.0	123.0
P4	127.7	148.8	188.8	169.9	148.8	183.1	139.4	119.4	166.5	149.5	127.9	146.4	122.0	149.1
Mean	160.4	179.8	193.6	171.9	184.6	193.1	189.1	155.2	151.7	179.7	159.3	180.1	166.0	
CD (0.05)	Variety (V)	19.16		Treatment(T)	9.20		Interaction	V	18.41	T	16.21			
SEM (±)			0.054				0.014					0.196		0.294

P1 = HQPM-1, P2 = VL Amber pop corn, P3 = Win orange sweet corn and P4 = Parkash
T1 = Control, T2 = Hydropriming, T3 = Hydropriming + Thiram (3g/kg of seed), T4 = Matrix priming with hydrogel, T5 = Halopriming (KNO_3: 0.3 %), T6 = Priming with fulvic acid : 0.1 %, T7 = Cruiser : 4 ml / kg of seed, T8 = Thiram: 3g/kg of seed, T9 = Kalisena : 8g/kg of seed, T10 = Priming with ceolomic fluid, T11 = Priming with vermiwash, T12 = Magnetic stimulation (1000 G/2h), T13 = Low temperature hydration (72h / 10 °C)

Table 3: Effect of seed enhancement treatments on days to flowering in maize genotypes

Treatments	Days to 50% anthesis*	Days to 50% silking*	ASI**
T_1	50.50	53.08	2.63
T_2	50.58	52.75	2.41
T_3	49.75	51.25	1.58
T_4	50.58	53.16	2.58
T_5	50.33	53.00	3.00
T_6	50.08	51.75	1.67
T_7	49.91	52.44	2.58
T_8	50.25	52.66	2.50
T_9	51.00	53.25	2.25
T_{10}	51.16	53.08	2.00
T_{11}	49.58	51.41	1.66
T_{12}	49.50	51.00	1.75
T_{13}	51.41	53.41	2.41
CD (0.05)	1.01	0.77	0.71

*Mean of four genotypes; **ASI: Anthesis silking interval
P1 = HQPM-1, P2 = VL Amber pop corn, P3 = Win orange sweet corn and P4 = Parkash
T1 = Control, T2 = Hydropriming, T3 = Hydropriming + Thiram (3g/kg of seed) , T4 = Matrix priming using hydrogel, T5 = Halopriming (KNO_3: 0.3 %), T6 = Priming with fulvic acid : 0.1 % , T7 = Cruiser : 4 ml / kg of seed, T8 = Thiram: 3g/kg of seed, T9 = Kalisena : 8g/kg of seed, T10 = Priming with ceolomic fluid, T11 = Priming with vermiwash, T12 = Magnetic stimulation (1000 G/2h) , T13 = Low temperature hydration (72h /10 °C)

or grain stage [18]. It was reported that, on-farm seed hydration in maize significantly improved field emergence, early seedling growth and yield under rain fed conditions [14]. Contrastingly, a previous study reported that these treatments had no effect on flowering and seed yield of maize genotypes [17]. In our study, the initial advantage of seed enhancement on seedling emergence and early vegetative growth persisted until maturity but the percentage gain over control due to seed enhancement treatments tapered in later growth stages. Seed enhancement treatments significantly increased seed yield (4.51-4.66%) and test weight (0.01-13.98%) as compared to control (Table 4). The higher yield in treated plots could be attributed to uniform crop stand, vigorous crop growth favoring better filling, higher number of filled cobs resulting in higher 100-seed weight and seed yield.

Genotype effect

The response of seed enhancement treatments is genotype-dependent [2] and influenced by vigour level of seed [19]. In the present study, differential responses to these treatments were more vigour dependent than genotype. Win orange sweet corn and Parkash were more responsive to these treatments as compared to VL Amber Popcorn and HQPM-1 as the former had low vigour (85 and 88% germination) than the latter (>95% germination). Compositional difference in genotypes had no evident effect on their response to these treatments.

Seed enhancement treatments

Seed priming based treatments were more effective among the treatments as seed priming initiates the metabolic processes in the seed required for seed germination, thus provides initial advantage in field performance as compared to control seeds.

Table 4. Effect of seed enhancement treatments on seed yield and test weight of maize genotypes

	Seed yield (kg/plot)													
	Treatment													
Variety	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	Mean
P1	13.73	14.80	15.76	14.33	15.26	15.46	14.50	15.06	14.13	14.46	15.40	16.13	13.20	14.78
P2	13.26	14.60	14.40	13.43	14.00	14.26	13.93	14.56	14.10	14.06	13.73	14.20	12.70	13.94
P3	11.40	12.03	11.76	12.00	12.33	11.67	11.33	11.90	11.80	11.60	10.76	11.46	10.33	11.49
P4	14.83	12.03	17.80	18.36	17.26	17.40	13.96	15.13	15.23	15.69	16.06	16.16	15.93	16.45
Mean	13.30	14.86	14.90	14.53	14.71	14.70	13.92	14.16	13.56	13.70	14.24	14.49	13.05	
CD (0.05)	Variety (V)	0.761		Treatment (T)	0.546		Interaction	V	1.09	T	2.03			
SEM (±)			0.224				0.345					0.321		0.521
Test weight (g)														
Treatments														
Variety	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	Mean
P1	19.02	24.52	24.35	23.57	19.21	20.97	23.57	24.38	23.03	20.39	23.75	21.08	21.84	22.34
P2	12.08	12.41	15.41	15.23	12.36	15.13	15.31	14.67	13.64	13.37	12.96	15.12	14.86	14.04
P3	11.43	12.43	12.68	12.96	11.74	12.80	11.55	11.75	11.56	12.39	11.29	11.52	11.68	11.98
P4	24.97	25.37	24.49	24.70	24.51	24.25	24.50	24.52	24.43	24.33	26.23	24.76	24.44	24.81
Mean	16.87	18.85	19.23	19.11	17.20	18.29	18.73	18.83	18.16	17.62	18.56	18.32	18.20	
CD (0.05)	Variety (V)		1.44		Treatment (T)	0.214		Interaction	V	0.490	T	0.532		
SEM (±)			0.112			0.047				0.225		0.129		

P_1 = HQPM-1, P2 = VL Amber pop corn, P3 = Win orange sweet corn and P_4 = Parkash

T_1 = Control, T_2 = Hydropriming, T_3 = Hydropriming + Thiram (3g/kg of seed), T_4 = Matrix priming using hydrogel, T_5 = Halopriming (KNO_3: 0.3 %), T_6 = Priming with fulvic acid : 0.1 %, T_7 = Cruiser : 4 ml / kg of seed, T_8 = Thiram: 3g/kg of seed, T_9 = Kalisena : 8g/kg of seed, T_{10} = Priming with ceolomic fluid, T_{11} = Priming with vermiwash, T_{12} = Magnetic stimulation (1000 G/2h), T_{13} = Low temperature hydration (72h / 10 °C)

Keeping the overall effect of the treatments, the most effective treatments were hydro-priming for 17 h at 20°C, followed by drying back and dry dressing with thiram @ 3g/kg of seed, halopriming with 0.3% KNO_3 and magneto priming (1000 G for 2h). Similar results were reported at low temperature conditions [6, 10, 12, 20].

The study validated the potential of pre-sowing seed enhancement treatments for improving field emergence, early vegetative growth, flowering manipulations and seed yield in maize during *Kharif* season. Most of the previous studies have shown efficacy of seed enhancement on field emergence and crop performance in winter or spring-summer maize, when the soil temperature is <15°C at the time of sowing. However, the present study established the advantage of seed priming in enhancing the planting value, even in the main *kharif* season.

ACKNOWLEDGEMENT

Acknowledgements are due to Dr. Ranvir Singh, ICAR-Indian Veterinary Research Institute, Izatnagar for providing earthworm products and Dr. DK Joshi, NRL, ICAR-IARI, New Delhi for undertaking magnetic treatments. The first author acknowledges ICAR for providing financial assistance (JRF) during course of study.

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