Research Article

Nutri-Seed Priming and Planting Geometry Effects on Growth and Oil Production of Sunflower Varieties under the Ecological Conditions of Tandojam, Sindh, Pakistan

Zulfiqar Ali Abbasi[1*], Muhammad Nawaz Kandhro[1], Aijaz Ahmed Soomro[1], Naimatullah Leghari[2], Muhammad Ibrahim Keerio[3], Ahmed Naqi Shah[1] and Musrat Begum Abro[1]

[1]Department of Agronomy, [2]Department of Farm Power and Machinery, [3]Department of Crop Physiology, Sindh Agriculture University, Tandojam, Pakistan.

Abstract | Seed priming improves germination, crop stand and finally the yield. Two years field study was undertaken to assess the effect of primed seeds with different solutions and planting geometries on growth and yield of sunflower in agro-ecological conditions of Tandojam, Pakistan. The experiments were a randomized complete block design in factorial combination, replicated three times. An experimental unit was accommodated with three factors i.e. seed priming sources (No seed priming, seeds priming with canal water, seed primed with 1.0% Urea, and seed primed with 0.2% $ZnSO_4$), planting geometries (i.e. 55 x 35 cm, 65 x 30 cm, 75 x 25 cm, and 85 x 20 cm), and sunflower varieties (HO-1 and Hysun-33). Analysis of data revealed a significant effect of seed priming, geometry, varieties, and their interactions on sunflower growth and yield components. The highest seed yield (kg ha^{-1}) and oil content (%) were reported for seed primed with 0.2% $ZnSO_4$, followed by seeds primed with 1.0% Urea. In case of planting geometry, the maximum seed yield (kg ha^{-1}) and oil content (%) were noticed under planting geometry of 85 x 20 cm, followed by 75 x 25 cm. The variety HO-1 proved better in overall performance. The interaction of seed priming with 0.2% $ZnSO_4$ and planting geometry of 85 x 20 cm produced the highest seed yield (kg ha^{-1}) and oil content (%), followed by seed priming with 0.2% $ZnSO_4$ and 75 x 25 cm planting geometry. It is concluded that sunflower yield could be enhanced substantially with seeds primed with 0.2% $ZnSO_4$ before sowing and arranged with planting geometry of 85 x 20 cm. The variety HO-1 is relatively a better option for sunflower cultivation under agro-climatic conditions of Tandojam, Pakistan.

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***Correspondence** | Zulfiqar Ali Abbasi, Department of Agronomy, Sindh Agriculture University, Tandojam, Pakistan; **Email:** zaabbasi786@gmail.com
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Introduction

Edible oil has been reported as one of the most important commodities of daily use in Pakistan (Khan and Akmal, 2016; Amjad, 2014). The country is facing acute deficit of edible oil and hence imported annually about 88% edible oil for its consumption (GoP, 2018). Pakistan is the 3rd largest importer of edible oil in the world (Soomro, 2015). Sunflower is a major oilseed crop after soybean, palm and rapeseed in the world (Shah et al., 2013). It ranks 2nd in Pakistan after cotton (Siddiqui, 2010). The crop is adapted well to the environmental conditions and prevailing cropping systems (Mahmood at al., 2018). In a study Bakhat et al. (2010) revealed that two seasons (spring and autumn) are suitable for the growing sunflower in Pakistan. During 2017-18, sunflower was cultivated on 82,186 hectares with production of 104,000 tones which yielded 40,000 tones oil (GoP, 2018). Buriro et al. (2015) reported that sunflower seed contains 47% oil, including vitamins A, D, E and K and linoleic acid. The sunflower oil consumption reduces the level of blood cholesterol (Kalaiyarasan and Vaiyapuri, 2007). The meal of sunflower seed is a good source of protein, used in livestock and poultry feed (Khalil and Jan, 2010). Fiber from the crop stem is used to make paper. Yellow dye is also obtained from flowers and purple black dye from seeds of sunflower (Tengong et al., 2010).

Priming of seeds is one of the important commercial processes, where germination rate and seedling stands in crops could be improved (Halmer, 2003). Seeds are kept in water or nutrient solution for certain period of time to regulate moisture or nutrient content, bringing them near to germination process and then sown in the field (Kouchebagh et al., 2014). The process involves advancing seed to a stage of germination, to enable fast and uniform emergence at planting (Dawal et al., 2017). Farming community can easily adopt many methods of seed priming for alleviating different stress levels. Furthermore, they can produce good quality seeds and use them for next crop cycle ultimately reducing costs of seed purchase (Chatterjee et al., 2018). Moeinzadeh et al. (2010) disclosed that seed priming caused improvement in vigour of sunflower. Priming of seeds with zinc could enhance metabolism of seeds and hence emergence and establishment of seedlings (Farooq et al., 2012).

Optimum plant density is a major concern in different crops (Akmal et al., 2014; Khan and Akmal, 2016). Planting of newly evolved sunflower varieties along with appropriate planting geometry is considered a reliable approach to increase production of edible oil for food security and reducing import bill (Zahoor et al., 2010). Ion et al. (2015) reported that optimum plant population depends on condition of crop growth. The findings of a study suggested that growth and yield traits of sunflower were superior under wider planting geometry (75 x 45 cm) but yield was low due to inappropriate stand (Amjed et al., 2013). Considering importance of nutri-seed priming with planting geometry, this study was conducted for increasing yield of sunflower.

Materials and Methods

Soil selection and experimental details

Field experiment was conducted at Students' Experimental Farm of Sindh Agriculture University, Tandojam, Pakistan during autumn 2017 and repeated on same land during autumn 2018. The experimental design was a randomized complete block, factorial arrangements in three replications. The size of an experimental unit was 6 m x 5 m (30 m^2). The soil of the experimental area was clay loam, which according to USDA system belongs to Order *Aridisols* and Sub-group *Typic camborthids*. The experimental field was ploughed two times with disc harrow, irrigated, dried to workable condition, levelled and finally seedbed was prepared by plowing with cultivator. The experiment consisted of four seed priming sources (No priming (seeds were not kept in water or nutrient solution), priming with canal water, priming with 1.0% Urea and priming with 0.2% $ZnSO_4$), four planting geometries (i.e. 55 x 35, 65 x 30, 75 x 25 and 85 x 20 cm), and two varieties (HO-1 and Hysun-33). The priming of seeds in canal water or nutrients solution was done in a plastic container at field for two hours and then seeds were sown immediately on same day in the field. For preparing 1.0% Urea solution, 1 kg of Urea fertilizer was dissolved in 100 liters' water whereas for preparing 0.2% zinc concentration, 200 g of $ZnSO_4$ were dissolved in 100 liters water. In 1st year of experiment, priming of seeds was done on August 01, 2017 while in 2nd year it was done on August 01, 2018. Sowing was done on same day of primed seed through single coulter hand drill. For maintaining proper plant to plant distance, thinning was done 15 days after sowing (DAS). The irrigation was applied keeping in view the soil condition and crop requirement. A total of five irrigations were applied at 15, 30, 45, 60 and 75 DAS. Each irrigation was applied to a level of farmer practice. The applications of N, P and K were 100, 50 and 50 (kg ha^{-1}) from Urea, SSP and SOP sources, respectively. The application of N was in three equal splits; i.e. 1st at planting time, 2nd at 1st irrigation (15 DAS) and 3rd at 3rd irrigation (45 DAS). All phosphorus and potassium were applied at the time of land preparation. Inter-culturing was done for controlling weeds before 1st, 2nd and 3rd irrigations, respectively.

Soil of the experimental area was analyzed before sowing and after harvesting (Table 1). Soil samples were taken with the help of soil auger at a depth of

0-20 cm from five locations of total experimental area before sowing and after harvesting of the crop. The soil samples were air-dried, ground, sieved (2 mm) and placed in plastic containers. The samples were analyzed for various physical and chemical properties following the procedures of Ryan et al. (2001). Soil texture was measured by Bouyoucos hydrometer method. Electrical conductivity (EC) and soil pH was measured in 1:2 soil water extract using EC and pH meters, respectively. Walkley Black method was followed for the determination of organic matter content. Total N was calculated. However, soil was extracted for determining extractable P and K using Ammonium bicarbonate di-ethylene triamine penta acetic acid (AB-DTPA).

Table 1: *Average physico-chemical properties of experimental soil for the year 2017 and 2018.*

Parameters	Before sowing	After harvesting
Soil texture		
%Sand	19.5	-
%Silt	42.0	-
%Clay	38.5	-
Textural class	Silty clay loam	
Soil chemical analysis		
Soil pH	8.70	8.40
Organic matter (%)	0.49	0.40
EC (dS m^{-1})	2.36	1.50
Available P (mg kg^{-1})	1.30	0.90
Extractable K (mg kg^{-1})	209	170
Total soil N (%)	0.02	0.02

Crop observations and measurement

The agronomic and physiological observations were recorded for parameters of economic importance such as seed germination (m^{-2}), leaf area index (%), crop growth rate (g m^{-2} d^{-1}), plant height (cm), head diameter (cm), seeds $head^{-1}$, seed weight $head^{-1}$ (g), 1000-seed weight (g), biological yield (kg ha^{-1}), seed yield (kg ha^{-1}), harvest index (%) and oil content (%). Seed germination per square meter was noted by counting the emerged seedlings at 10 days after sowing. Leaf area index (%) was measured at peak vegetative growth from randomly selected five plants by the formula: Leaf area $plant^{-1}$ (cm^2) ÷ Ground area $plant^1$ (cm^2). Crop growth rate (g m^{-2} d^{-1}) was recorded from five tagged plants using the formula: (W2 – W1) ÷ (T2 –T1) at peak vegetative growth. Plant height (cm) was measured with the help of measuring tape from base to the top at maturity from five selected plants. Head diameter (cm) was noticed with the help of measuring tape at maturity from five tagged plants. Seeds $head^{-1}$ were counted from five selected plants. Seed weight $head^{-1}$ (g) was noted from five tagged plants by weighing seeds on digital balance. Seed index (g) was recorded by weighing 1000 seeds on digital balance obtained from five selected plants. Biological yield (kg a^{-1}) was noted by averaging the biomass weight of five tagged plants added to the biological yield of net experimental area of plot to estimate the biological yield per hectare according to the formula: Biological yield $plot^{-1}$ (kg) ÷ Area $plot^{-1}$ (m^2) × 10000. Seed yield (kg ha^{-1}) was recorded from plants harvested for biological yield. The seeds of selected plants were shelled from head, sun dried and weighed using the formula: = Seed yield $plot^{-1}$ (kg) ÷ Area $plot^{-1}$ (m^2) × 10000. Harvest index (%) was calculated as per the formula: Seed yield (kg ha^{-1}) ÷ Biological yield (kg ha^{-1}) × 100. Oil was extracted by using 10 g seed for each treatment through Soxhlete apparatus available at Oilseeds Research Institute, Agriculture Research Centre, Tandojam by adopting proper method. The oil content % was calculated according to the formula: Weight of oil (g) ÷ Weight of seed sample (g) × 100. The pooled data of each parameter for both years (2017 and 2018) is given below in respective tables.

Statistical analysis

The data were statistically analyzed following ANOVA technique using software Statistix version 8.1 (Statistix, 2006). The least significant difference (LSD) test was used at alpha 0.05 for comparing differences of treatments.

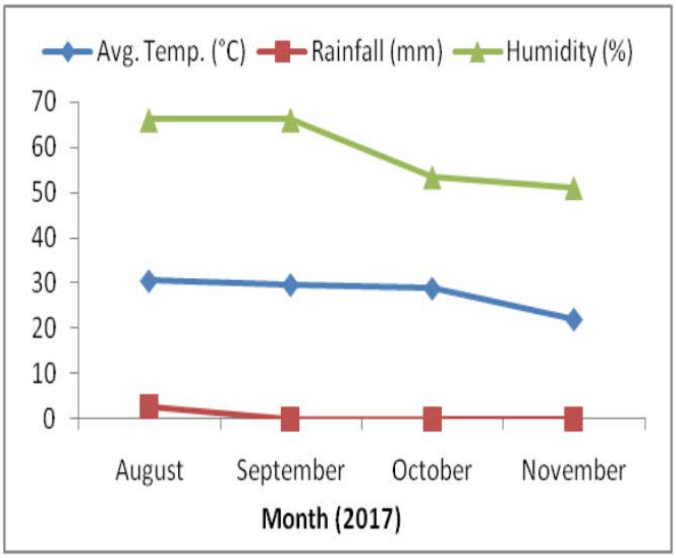
Meteorological data

The meteorological data of Tandojam during experimental seasons of both years (2017 and 2018) were obtained from Meteorological Station, Tandojam. The details of meteorological data on monthly basis for August, September, October and November regarding average temperature (°C), Rainfall (mm) and humidity (%) are presented in Figure 1.

Results and Discussion

Seed germination (m^{-2})

Optimum germination is pre-requisite for the desired seedlings per unit area, which ensures high yield. The statistical analysis of the data showed a significant ($p \leq 0.05$) effect on germination for seed priming, geometry and interaction of seed priming x geometry whereas non-significant ($p \geq 0.05$) effect for varieties including interaction of seed priming x geometry, seed priming x varieties, geometry x varieties and seed priming x geometry x varieties (Table 2). The seed priming with 0.2% $ZnSO_4$ gave higher seed germination followed by seed priming with 1.0% Urea. In case of planting geometry, highest seed germination was recorded in the geometry of 85 x 20 cm than all other planting geometries followed by 75 x 25 cm. The possibility of improved seed germination under priming with zinc might be due to synthesis of Auxin in seeds (Rashid and Memon, 2001). The highest seed germination under the geometry 85 x 20 cm may be associated with optimum row and plant spacing. Previously, in a study, the population of sunflower plants was affected by planting densities, being higher in narrow while lower in wider row spacing (Khan and Akmal, 2016).



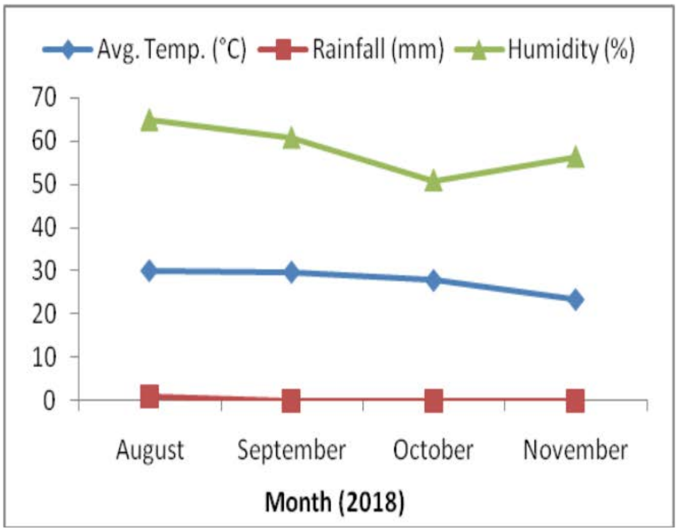


Figure 1: *Meteorological data of Tandojam for crop growth season of sunflower during 2017 and 2018.*

Table 2: *Seed germination (m^{-2}) of different varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry (cm)				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	4.7	4.7	4.7	4.7	4.7
	Canal water	5.3	5.7	6.0	6.7	5.9
	1.0% Urea	5.7	6.0	6.7	7.0	6.4
	0.2% $ZnSO_4$	6.0	6.7	7.0	7.7	6.9
	Mean	5.4	5.8	6.1	6.5	6.0
Hysun-33	No priming	4.7	4.7	4.7	4.7	4.7
	Canal water	5.3	5.7	6.0	6.7	5.9
	1.0% Urea	5.7	6.0	6.7	7.0	6.4
	0.2% $ZnSO_4$	6.0	6.7	7.0	7.7	6.9
	Mean	5.4	5.8	6.1	6.5	6.0
Averages	No priming	4.7	4.7	4.7	4.7	4.7 c
	Canal water	5.3	5.7	6.0	6.7	5.9 b
	1.0% Urea	5.7	6.0	6.7	7.0	6.4 b
	0.2% $ZnSO_4$	6.0	6.7	7.0	7.7	6.9 a
	Mean	5.4 c	5.8 b	6.1 b	6.5 a	
Variables		**SE**		**p-value**		**LSD 5%**
Priming (P)		0.1643		0.0288		0.3284
Geometry (G)		0.1643		0.0000		0.3284
Varieties (V)		0.1162		0.7211		0.2322
P × G		0.3286		0.0029		0.6569
P ×V		0.2324		0.9428		0.4645
G × V		0.2324		0.9428		0.4645
P × G × V		0.4647		0.9988		0.9289

Leaf area index (%)

Seed priming, planting geometry, varieties, and interaction of seed priming x varieties, geometry x varieties, seed priming x geometry, and seed priming x geometry x varieties caused a substantial ($p \leq 0.05$) impact on leaf area index (Table 3). Data showed that seed priming with 0.2% $ZnSO_4$ resulted in considerably ($p \leq 0.05$) greater leaf area index, followed by seed priming with 1.0% Urea. As regards planting geometry, significantly ($p < 0.05$) highest leaf area index was noticed under the geometry of 85 x 20 cm, followed by 75 x 25 cm. Variety HO-1 proved better in leaf area index in contrast to Hysun-33. The higher and statistically equal (LSD5% = 0.4758) leaf area index was reported in 0.2% $ZnSO_4$ priming with 85 x 20 cm and 0.2% $ZnSO_4$ priming with 75 x 25 cm. Greatest leaf area index was noted in the integration of HO-1 x priming with 0.2% $ZnSO_4$. The interaction of variety HO-1 x geometry of 85 x 20 cm produced highest leaf area-index. The maximum leaf areas index was observed in the interaction of 0.2% $ZnSO_4$ x geometry of 85 x 20 cm x variety HO-1. The better leaf area index with zinc priming may be attributed to active role of zinc for several enzymes including carbonic anhydrates, alcohol dehydrogenises and RNA polymerase (Rehman et al., 2015). The highest leaf area index under the geometry of 85 x 20 cm may be associated to greatest growth of plant due to optimum row and plant spacing. Mehrpouyan et al. (2010) suggested the positive impact of planting densities on leaf area index of sunflower.

Table 3: *Leaf area index (%) of two varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming Sources	Planting geometry (cm)				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	10.8 n	11.1 mn	12.0 kl	12.6 k	11.6 f
	Canal water	13.7 j	16.7 f	17.1 ef	17.8 e	16.3 d
	1.0% Urea	15.7 g	18.9 d	19.1 cd	19.5 bcd	18.3 b
	0.2% $ZnSO_4$	17.8 e	19.7 bc	20.1 b	21.1 a	19.7 a
	Mean	14.5 d	16.6 c	17.1 b	17.8 a	16.5 a
Hysun-33	No priming	8.8 p	9.2 op	9.8 o	10.8 n	9.7 g
	Canal water	10.7 n	11.9 kl	11.8lm	11.9 kl	11.6 f
	1.0% Urea	12.7 k	14.0 ij	14.6 hi	14.9 gh	14.1 e
	0.2% $ZnSO_4$	14.1 ij	15.5 g	20.1 b	17.1 ef	16.7 c
	Mean	11.6 g	12.7 f	14.1 e	13.7 e	13.0 b
Averages	No priming	9.8 k	10.2 k	10.9 j	11.7 i	10.6 d
	Canal water	12.2 i	14.3 gh	14.5 gh	14.9 g	14.0 c
	1.0% Urea	14.2 h	16.5 ef	16.9 de	17.2 cd	16.2 b
	0.2% $ZnSO_4$	16.0 f	17.6 c	20.1 a	19.1 b	18.2 a
	Mean	13.0 c	14.6 b	15.6 a	15.7 a	-
Variables		SE	p-value		LSD 5%	
Priming (P)		0.1683	0.0000		0.3364	
Geometry (G)		0.1190	0.0000		0.2379	
Varieties (V)		0.1683	0.0000		0.3364	
P × G		0.2380	0.0001		0.4758	
P ×V		0.3366	0.0001		0.6729	
G × V		0.2380	0.0014		0.4758	
P × G × V		0.1683	0.0000		0.3364	

Crop growth rate ($g\ m^{-2}\ d^{-1}$)

Crop growth rate was significantly ($p \leq 0.05$) impacted by seed priming, geometry and varieties including interaction of seed priming x varieties, geometry x varieties whereas, non-substantially ($p > 0.05$) by combination of seed priming x geometry and seed priming x geometry x varieties (Table 4). The results demonstrated that seed priming with 0.2% $ZnSO_4$ produced greater crop growth rate followed by seed priming with 1.0% Urea. With respect to planting geometry, highest crop growth rate was recorded in the planting geometry of 85 x 20 cm followed by 75 x 25 cm. Among varieties, HO-1 proved better in crop growth rates as compared to Hysun-33. The interaction of HO-1 x seed priming with 0.2% $ZnSO_4$ resulted in higher crop growth. The interaction of variety HO-1 with geometry 85 x 20 cm produced greatest crop growth rate. The enhanced crop growth in zinc primed plots may be associated with active role of zinc for several enzymes (Rehman et al., 2015). The optimum row and plant spacing was the possible cause of higher crop growth rate under the geometry 85 x 20 cm. Jafri et al. (2015) concluded that seed priming caused boost in growth of sunflower.

Table 4: *Crop growth rate ($g\ m^{-2}\ d^{-1}$) of two varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry (cm)				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	0.6	0.6	0.7	0.8	0.7 f
	Canal water	1.4	1.3	1.5	2.1	1.6 d
	1.0% Urea	1.5	2.9	3.0	3.1	2.6 b
	0.2% $ZnSO_4$	2.5	3.1	3.7	4.0	3.3 a
	Mean	1.5 e	2.0 c	2. 2b	2.5 a	2.1 a
Hysun-33	No priming	0.4	0.5	0.4	0.7	0.5 f
	Canal water	1.1	1.0	1.2	1.2	1.1 e
	1.0% Urea	1.4	2.1	2.7	2.9	2.3 c
	0.2% $ZnSO_4$	1.9	2.9	2.9	3.0	2.7 b
	Mean	1.2 f	1.6 de	1.8 d	2.0 c	1.6 b
Averages	No priming	0.5	0.6	0.6	0.8	0.6 d
	Canal water	1.3	1.2	1.4	1.7	1.4 c
	1.0% Urea	1.5	2.5	2.9	3.0	2.5 b
	0.2% $ZnSO_4$	2.2	3.0	3.3	3.5	3.0 a
	Mean	1.4 d	1.8 c	2.0 b	2.2 a	-
Variables		SE		p-value		LSD 5%
Priming (P)		0.1243		0.0499		0.2485
Geometry (G)		0.0879		0.0029		0.1757
Varieties (V)		0.1243		0.0000		0.2485
P × G		0.1758		0.3660		-
P ×V		0.2487		0.0397		0.4971
G × V		0.1758		0.1597		-
P × G × V		0.3517		0.5225		-

Plant height (cm)

A considerable ($p \leq 0.05$) influence on plant height was noted for seed priming, geometry, varieties including interaction of varieties x geometry, and seed priming x geometry whereas, non-significant ($p > 0.05$) for interaction of seed priming x varieties, and seed priming x geometry x varieties (Table 5). The seed priming with 0.2% $ZnSO_4$ produced tallest plants, followed by seed priming with 1.0% Urea. In case of geometry, greatest plant height was recorded in the geometry of 85 x 20 cm, followed by geometry 75 x 25 cm. Variety HO-1 gave higher plant height against Hysun-33. The interaction of HO-1 with geometry of 85 x 20 cm showed tallest plants. The integration of seed priming with 0.2% $ZnSO_4$ and 85 x 20 cm resulted in greater plant height. Rehman et al. (2015) suggested that higher plant height in zinc primed treatments may be attributed to active role of zinc for several enzymes including carbonic anhydrates, alcohol dehydrogenases and RNA polymerase. The tall plants in geometry of 85 x 20 cm were probably due to greater growth under optimum row and plant spacing. In another study, planting geometry caused significant effect on the height of plants (Vijayaakshmi et al., 2017).

Table 5: *Plant height (cm) of different varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry (cm)				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	144	155	167	179	161
	Canal water	168	176	184	188	179
	1.0% Urea	185	196	198	200	195
	0.2% $ZnSO_4$	200	202	206	208	204
	Mean	174 d	182 c	189 b	194 a	185 A
Hysun-33	No priming	127	132	137	143	135
	Canal water	148	152	156	163	154
	1.0% Urea	164	167	169	171	168
	0.2% $ZnSO_4$	173	174	175	177	175
	Mean	153 h	156 g	159 f	163 e	158 B
Averages	No priming	135 k	144 j	152 i	161 gh	148 d
	Canal water	158 h	164 g	170 f	175 e	167 c
	1.0% Urea	175 e	182 d	183 cd	185 cd	181 b
	0.2% $ZnSO_4$	187 bc	188 bc	191 ab	193 a	189 a
	Mean	164 d	169 c	174 b	178 a	-

Variables	SE	p-value	LSD 5%
Priming (P)	1.0574	0.0000	2.1137
Geometry (G)	1.0574	0.0000	2.1137
Varieties (V)	0.7477	0.0000	1.4946
P × G	2.1148	0.0000	4.2274
P ×V	1.4954	0.1172	2.9893
G × V	1.4954	0.0003	2.9893
P × G × V	2.9908	0.2560	5.9785

Head diameter (cm)

The yield potential of sunflower crop depends upon the size of head. It is evident from the data that seed priming, geometry, varieties, and interaction of seed priming x varieties showed a significant ($p \leq 0.05$) effect on head diameter whereas, non-significant ($p \geq 0.05$) effect for interaction of seed priming x geometry, geometry x varieties and seed priming x geometry x varieties was noticed (Table 6). The results indicated that seed priming with 0.2% $ZnSO_4$ gave highest head diameter, followed by seed priming with 1.0% Urea. The planting geometry of 85 x 20 cm conferred greatest head diameter, followed by 75 x 25 cm. HO-1 gave more head diameter in comparison to Hysun-33. The highest head diameter was recorded in the interaction of variety HO-1 x seed priming with 0.2% $ZnSO_4$. Moeinzadeh et al. (2010) suggested that seed priming caused improvement in sunflower head diameter. Plant density caused substantial influence on sunflower head diameter in a recent study (Mokhtari and Moosavi, 2016).

Table 6: *Head diameter (cm) of different varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry (cm)				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	23.1	23.7	24.0	25.3	24.0 e
	Canal water	24.9	25.0	26.0	26.8	25.7 cd
	1.0% Urea	26.0	26.2	27.8	28.2	27.1 b
	0.2% $ZnSO_4$	27.0	28.9	29.2	30.9	29.0 a
	Mean	25.3	26.0	26.8	27.8	26.5 A
Hysun-33	No priming	22.4	22.7	23.6	24.0	23.2 f
	Canal water	23.0	24.0	25.0	25.1	24.3 e
	1.0% Urea	24.6	25.0	25.6	26.1	25.3 d
	0.2% $ZnSO_4$	25.8	26.0	26.6	27.0	26.4 bc
	Mean	24.0	24.4	25.2	25.6	24.8 B
Averages	No priming	22.8	23.2	23.8	24.7	23.6 d
	Canal water	24.0	24.5	25.5	26.0	25.0 c
	1.0% Urea	25.3	25.6	26.7	27.2	26.2 b
	0.2% $ZnSO_4$	26.4	27.5	27.9	29.0	27.7 a
	Mean	24.6 d	25.2 c	26.0 b	26.7 a	-

Variables	SE	p-value	LSD 5%
Priming (P)	0.2690	0.0000	0.5377
Geometry (G)	0.2690	0.0000	0.5377
Varieties (V)	0.1902	0.0000	0.3802
P × G	0.5380	0.9859	1.0754
P ×V	0.3804	0.0146	0.7604
G × V	0.3804	0.3371	0.7604
P × G × V	0.7608	0.7491	1.5209

Seeds head^{-1}

The number of seeds head^{-1} represents the yield of crop. The analysis of variance indicated a considerable ($p \leq 0.05$) influence on seeds head^{-1} for seed priming, geometry, varieties including integration of seed priming x varieties, whereas non-substantial ($p \geq 0.05$) effect for interaction of seed priming x geometry, geometry x varieties, and seed priming x geometry x varieties (Table 7). The data denoted that seed priming with 0.2% $ZnSO_4$ resulted in greatest seeds head^{-1}, followed by seed priming with 1.0% Urea. The geometry of 85 x 20 cm produced highest seeds head^{-1}, followed by 75 x 25 cm. The variety HO-1 proved better by producing higher number of seeds head^{-1} in contrast to Hysun-33. The interaction of variety HO-1 x seed priming with 0.2% $ZnSO_4$ gave greatest seeds number head^{-1}. The increased number of seeds head^{-1} in zinc primed plots may be linked to active role of zinc for several enzymes (Rehman et al., 2015). The optimum plant spacing was the possible cause of higher seeds number head^{-1} in the geometry of 85 x 20 cm. Positive impact of planting densities on seeds head^{-1} of sunflower was also reported by Hekmat (2013).

Table 7: *Seeds head^{-1} of different varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry (cm)				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	671	799x	852x	859	795 f
	Canal water	933	981	1017	1077	1002 cd
	1.0% Urea	1088	1161	1181	1241	1168 b
	0.2% $ZnSO_4$	1199	1278	1297	1302	1269 a
	Mean	973 b	1055 a	1087 a	1120 a	1059a
Hysun-33	No priming	626	734	774	793	732 f
	Canal water	888	900	939	949	919 e
	1.0% Urea	908x	946	1009	1047	978 de
	0.2% $ZnSO_4$	998	1071	1097	1102	1067 c
	Mean	855 c	913b c	955x b	973 b	924 b
Averages	No priming	649	767	813	826	764 d
	Canal water	911	941	978	1013	961 c
	1.0% Urea	998	1054	1095	1144	1073 b
	0.2% $ZnSO_4$	1098	1174	1197	1202	1168 a
	Mean	914 c	984 b	1021 ab	1046 a	-
Variables		**SE**		**p-value**		**LSD 5%**
Priming (P)		27.993		0.0000		55.957
Geometry (G)		27.993		0.0001		55.957
Varieties (V)		19.794		0.0000		39.568
P × G		55.986		0.9727		111.91
P ×V		39.588		0.0272		79.135
G × V		39.588		0.9571		79.135
P × G × V		79.176		1.0000		158.27

Table 8: *Seed weight head^{-1} (g) of different varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry cm				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	63.1	81.9	87.9	84.7	79.4 f
	Canal water	80.6	100.1	104.2	105.4	97.6d e
	1.0% Urea	96.1	116.8	129.4	121.6	116.0 b
	0.2% $ZnSO_4$	114.7	131.8	134.9	133.8	128.8 a
	Mean	88.6 d	107.7ab	114.1a	111.4 a	105.4 a
Hysun-33	No priming	62.2	68.6	76.3	85.1	73.1 f
	Canal water	76.3	96.7	98.7	101.5	93.3 e
	1.0% Urea	86.4	105.9	106.1	107.8	101.6 d
	0.2% $ZnSO_4$	105.3	109.9	110.5	110.8	109.1 c
	Mean	82.6 d	95.3 c	97.9 c	101.3bc	94.3 b
Averages	No priming	62.7 j	75.3 i	80.5hi	86.5gh	76.2 d
	Canal water	78.5 hi	98.4 ef	102.1de	102.9cde	95.4 c
	1.0% Urea	91.3 fg	111.4bc	113.9ab	118.6ab	108.8 b
	0.2% $ZnSO_4$	110.0 bcd	120.9 a	122.2a	122.9a	119.0 a
	Mean	85.6 c	101.5 b	104.6ab	107.7a	-
Variables		**SE**		**p-value**		**LSD 5%**
Priming (P)		2.2771		0.0000		4.5519
Geometry (G)		2.2771		0.0000		4.5519
Varieties (V)		1.6102		0.0000		3.2187
P × G		4.5542		0.4996		9.1037
P ×V		3.2203		0.0040		6.4373
G × V		3.2203		0.3373		6.4373
P × G × V		6.4406		0.8572		12.875

Seed weight head^{-1} (g)

A significant ($p \leq 0.05$) effect on seed weight head^{-1} was noticed by seed priming, geometry and varieties including interaction of seed priming x varieties, geometry x varieties whereas, non-substantial ($p > 0.05$) effect was observed for seed priming x geometry and seed priming x geometry x varieties (Table 8). The results indicated that seed priming with 0.2% $ZnSO_4$ gave higher seed weight head^{-1}, followed by seed priming with 1.0% Urea. The highest seed weight head^{-1} was reported in geometry of 85 x 20 cm, followed by 75 x 25 cm. Among varieties, HO-1 surpassed Hysun-33 in seed weight head^{-1}. The greatest seed weight head^{-1} was found in the interaction of 0.2% $ZnSO_4$ x geometry of 85 x 20 cm. The combination of variety HO-1 x seed priming with 0.2% $ZnSO_4$ produced highest seed weight head^{-1}. The interaction of variety HO-1 x geometry of 85 x 20 cm gave greatest seed weight head^{-1}. The possibility of improved seed weight head^{-1} in priming with zinc might be due to synthesis of Auxin or indole acetic acid in seeds (Rashid and Memon, 2001). The highest seed weight head^{-1} with the geometry of 85 x 20 cm may be associated to optimum row and plant spacing. Planting densities caused positively significant impact on sunflower seed weight head^{-1} (Rasool et al., 2015).

Table 9: *1000-seed weight (g) of different varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry (cm)				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	66.7	67.7	68.3	68.7	67.8
	Canal water	69.3	80.0	80.0	80.7	77.5
	1.0% Urea	72.7	81.0	81.7	83.3	79.7
	0.2% $ZnSO_4$	75.0	81.7	90.0	91.7	84.6
	Mean	70.9	77.6	80.0	81.1	77.4 A
Hysun-33	No priming	64.0	65.1	66.3	66.7	65.5
	Canal water	67.7	75.0	73.3	76.7	73.2
	1.0% Urea	70.0	78.3	75.0	78.3	75.4
	0.2% $ZnSO_4$	73.3	80.0	85.0	88.3	81.7
	Mean	68.8	74.6	74.9	77.5	73.9 B
Averages	No priming	65.4	66.4	67.3	67.7	66.7 d
	Canal water	68.5	77.5	76.7	78.7	75.3 c
	1.0% Urea	71.4	79.7	78.4	80.8	77.5 b
	0.2% $ZnSO_4$	74.2	80.9	87.5	90.0	83.1 a
	Mean	69.8 b	76.1 a	77.5 a	79.3 a	-
Variables		**SE**		**p-value**		**LSD 5%**
Priming (P)		1.6099		0.0000		3.2181
Geometry (G)		1.6099		0.0000		3.2181
Varieties (V)		1.1383		0.0035		2.2755
P × G		3.2197		0.1546		6.4361
P ×V		2.2767		0.9005		4.5510
G × V		2.2767		0.8302		4.5510
P × G × V		4.5534		0.9999		9.1021

1000-seed weight (g)

Seed index is a key indicator to attain optimal weight of seeds. Seed priming, geometry and varieties showed a substantial ($p \leq 0.05$) effect impact on seed index whereas, the interaction of seed priming x geometry, seed priming x varieties, geometry x varieties, and seed priming x geometry x varieties caused a non-substantial ($p > 0.05$) impact on seed index (Table 9). The seed priming with 0.2% $ZnSO_4$ conferred highest seed index, followed by seed priming with 1.0% Urea. The greatest seed index was noted in geometry of 85 x 20 cm, followed by 75 x 25 cm. The variety HO-1 proved better in seed index as compared to Hysun-33. The enhanced seed index with zinc priming may be attributed to active role of zinc for several enzymes including RNA polymerase, carbonic anhydrate and alcohol dehydrogenises (Rehman et al., 2015). Seed priming caused improvement in seed index (Jafri et al., 2015). The highest seed index in the geometry of 85 x 20 cm may be associated to optimum plant growth. Kazemeini et al. (2009) suggested positive effect of planting density on seed index of sunflower.

Table 10: *Biological yield (kg ha^{-1}) of different varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry cm				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	6536	6623	6796	7035	6748 e
	Canal water	7660	7350	7723	7903	7659 d
	1.0% Urea	8483	10106	12523	12633	10936 b
	0.2% $ZnSO_4$	8583	11753	12640	12963	11485 a
	Mean	7815 d	8958 b	9920 a	10133a	9207 a
Hysun-33	No priming	6516	6556	6728	6900	6675 e
	Canal water	7346	7280	7436	7830	7473 d
	1.0% Urea	8226	9856	10130	10133	9586 c
	0.2% $ZnSO_4$	8313	10106	10393	10490	9825 c
	Mean	7600 d	8450 c	8672 bc	8838 b	8390 b
Averages	No priming	6526 h	6590 h	6762 h	6968gh	6711 d
	Canal water	7503 ef	7315fg	7580 ef	7866 e	7566 c
	1.0% Urea	8355 d	9981c	11326ab	11383a	10261 b
	0.2% $ZnSO_4$	8448 d	10930b	11516 a	11726a	10655 a
	Mean	7708 c	8704 b	9296 a	9486 a	-
Variables		**SE**		**p-value**		**LSD 5%**
Priming (P)		116.57		0.0000		233.02
Geometry (G)		116.57		0.0000		233.02
Varieties (V)		82.427		0.0000		164.77
P × G		233.14		0.0000		466.04
P ×V		164.85		0.0000		329.54
G × V		164.85		0.0000		329.54
P × G × V		329.71		0.0004		659.08

Biological yield (kg ha^{-1})

The analysis of variance indicated a considerable ($p \leq 0.05$) influence on biological yield for seed priming, geometry, varieties, interaction of seed priming x varieties, geometry x varieties, seed priming x geometry, and seed priming x geometry x varieties (Table 10). The results revealed that seed priming with 0.2% $ZnSO_4$ resulted in greatest biological yield, followed by seed priming with 1.0% Urea. The highest biological yield was recorded in the geometry of 85 x 20 cm, followed by 75 x 25 cm. Among varieties, HO-1 proved better in contrast to Hysun-33. The interaction of priming with 0.2% $ZnSO_4$ x geometry of 85 x 20 cm gave highest biological yield. The integration of variety HO-1 with seed priming with 0.2% $ZnSO_4$ produced greatest biological yield. The interaction of HO-1 x geometry of 85 x 20 cm gave highest biological yield. The enhanced biological yield in zinc primed plots may be due to active role of zinc for several enzymes (Rehman et al., 2015). Mrda et al. (2010) displayed that seed priming increased biological yield of sunflower plants. The higher biological yield in geometry of 85 x 20 cm was perhaps due to optimum row and plant spacing. Positive impact of planting densities on biological yield of sunflower was reported by Tavakoli (2013).

Table 11: *Seed yield (kg ha^{-1}) of different varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry (cm)				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	1800	1880	1886	1896	1865 d
	Canal water	1870	1913	1953	2036	1943 c
	1.0% Urea	2200	2263	2528	2540	2383 b
	0.2% $ZnSO_4$	2286	2393	2550	2596	2456 a
	Mean	2039ef	2112cd	2229ab	2267 a	2162 a
Hysun-33	No priming	1773	1805	1813	1821	1803 d
	Canal water	1820	1876	1883	1896	1869 d
	1.0% Urea	2160	2243	2468	2476	2337 b
	0.2% $ZnSO_4$	2260	2370	2475	2486	2397 ab
	Mean	2003f	2073de	2160 c	2170bc	2101 b
Averages	No priming	1786	1842	1850	1858	1834 d
	Canal water	1845	1895	1918	1966	1906 c
	1.0% Urea	2180	2253	2498	2508	2360 b
	0.2% $ZnSO_4$	2273	2381	2512	2541	2427 a
	Mean	2021c	2093b	2194 a	2218a	-
Variables		**SE**		**p-value**		**LSD 5%**
Priming (P)		23.965		0.0000		47.905
Geometry (G)		23.965		0.0000		47.905
Varieties (V)		16.946		0.0007		33.874
P × G		47.929		0.0005		95.810
P ×V		33.891		0.9491		67.748
G × V		33.891		0.5379		67.748
P × G × V		67.783		0.9994		135.50

Seed yield (kg ha^{-1})

Seed yield is a major decision used in agricultural crop. It refers as output produced per unit area. A significant ($p \leq 0.05$) effect on seed yield was noticed for seed priming, geometry, varieties and integration of seed priming x geometry, whereas non-substantial ($p \geq 0.05$) effect was observed for the interaction of seed priming x varieties, geometry x varieties, and seed priming x geometry x varieties (Table 11). The results illustrated that highest seed yield was recorded in seed priming with 0.2% $ZnSO_4$,followed by seed priming with 1.0% Urea. The greatest and statistical similar seed yield was noted in the geometry of 85 x 20 cm and 75 x 25. The variety HO-1 produced highest seed yield as compared to Hysun-33. The interaction of seed priming with 0.2% $ZnSO_4$ x geometry of 85 x 20 cm resulted in highest seed yield. The possibility of improved seed yield in priming with zinc may be attributed to its active role for several enzymes including carbonic anhydrate, alcohol dehydrogenises and RNA polymerase (Rehman et al., 2015). The increased seed yield in the geometry of 85 x 20 cm may be associated to optimum growth and population of plants. Positive impact of planting geometries on seed yield of sunflower was also reported by Khan and Akmal (2016).

Table 12: *Harvest index (%) of different varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry (cm)				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	20.6	23.7	21.6	25.4	22.8
	Canal water	19.7	24.4	25.1	27.7	24.2
	1.0% Urea	25.8	25.4	26	29.7	26.7
	0.2% $ZnSO_4$	27	27	28.4	29.9	28.1
	Mean	23.3 c	25.1 c	25.3 b	28.2 a	25.5 a
Hysun-33	No priming	19.8	20.6	24.5	24.9	22.5
	Canal water	20.3	23.6	24.9	28.6	24.4
	1.0% Urea	25.3	24.3	25.8	29.4	26.2
	0.2% $ZnSO_4$	27.8	26.6	27.7	29.8	28.0
	Mean	23.3 c	23.8 b	25.7 b	28.2 a	25.2 b
Averages	No priming	20.2 gh	22.2 fg	23.1 fg	25.2 e	22.6 d
	Canal water	20.0 h	24.0 ef	25.0 de	28.2ab	24.3 c
	1.0% Urea	25.6 de	24.9 de	25.9cde	29.6ab	26.5 b
	0.2% $ZnSO_4$	27.4 abc	26.8bcd	28.1abc	29.9 a	28.0 a
	Mean	23.3 c	24.5 b	25.5 b	28.2 a	-
Variables		**SE**		**p-value**		**LSD 5%**
Priming (P)		0.4732		0.0000		0.9459
Geometry (G)		0.4732		0.0000		0.9459
Varieties (V)		0.3346		0.0405		0.6688
P × G		0.9464		0.0001		1.8918
P ×V		0.6692		0.4193		1.3377
G × V		0.6692		0.0000		1.3377
P × G × V		1.3384		0.0009		2.6754

Harvest index (%)

Harvest index was significantly ($p\leq0.05$) impacted by seed priming, geometry, varieties, and interaction of seed priming x varieties, geometry x varieties whereas, non-substantially ($p>0.05$) by seed priming x geometry, and seed priming x geometry x varieties (Table 12). The data revealed that seed priming with 0.2% $ZnSO_4$ resulted in more harvest index, followed by seed priming with 1.0% Urea. The geometry of 85 x 20 cm gave highest harvest index, followed by 75 x 25 cm. The HO-1 proved better in performance over Hysun-33. The interaction of HO-1 x seed priming with 0.2% $ZnSO_4$ gave higher harvest index. The interaction of HO-1 x geometry of 85 x 20 cm resulted in greater harvest index. A boost in harvest index of sunflower was observed by seed priming (Jafri et al., 2015). Planting densities affected positively to sunflower harvest index (Ion et al., 2015).

Table 13: *Oil content (%) of different varieties of sunflower as influenced by seed priming and planting geometry.*

Varieties	Seed priming sources	Planting geometry (cm)				Mean
		55 x 35	65 x 30	75 x 25	85 x 20	
HO-1	No priming	36.7	36.9	37.1	37.5	37.1
	Canal water	38.1	39.0	39.7	39.7	39.1
	1.0% Urea	39.7	40.0	41.0	41.7	40.6
	0.2% $ZnSO_4$	40.4	41.8	42.4	42.7	41.8
	Mean	38.7	39.4	40.1	40.4	39.7 A
Hysun-33	No priming	35.8	36.0	36.3	36.7	36.2
	Canal water	37.6	38.4	38.5	38.6	38.3
	1.0% Urea	38.5	39.3	39.4	40.6	39.5
	0.2% $ZnSO_4$	39.0	40.9	41.2	41.4	40.6
	Mean	37.7	38.7	38.9	39.3	38.6B
Averages	No priming	36.3 h	36.5gh	36.7gh	37.1 g	36.6 d
	Canal water	37.9 f	38.7 e	39.1de	39.2de	38.7 c
	1.0% Urea	39.1 de	39.7cd	40.2 c	41.2 b	40.0 b
	0.2% $ZnSO_4$	39.7 cd	41.4 b	41.8ab	42.1 a	41.2 a
	Mean	38.2 d	39.0 c	39.5 b	39.9 a	-
Variables		**SE**		**p-value**		**LSD 5%**
Priming (P)		0.1590		0.0000		0.3179
Geometry (G)		0.1590		0.0000		0.3179
Varieties (V)		0.1125		0.0000		0.2248
P × G		0.3181		0.0061		0.6358
P ×V		0.2249		0.4816		0.4496
G × V		0.2249		0.6564		0.4496
P × G × V		0.4498		0.9731		0.8992

Oil content (%)

The value of sunflower crop depends upon its oil content percentage. The analysis of variance illustrated a substantial ($p\leq0.05$) impact on oil content for seed priming, geometry, varieties, and interaction of seed priming x geometry while non-substantial ($p>0.05$) effect was noticed for interaction of seed priming x varieties, geometry x varieties, and seed priming x geometry x varieties (Table 13). The results showed that highest oil content was noted in seed priming with 0.2% $ZnSO_4$, followed by seed priming with 1.0% Urea. The planting geometry of 85 x 20 cm gave greatest oil content, followed by 75 x 25 cm. The variety HO-1 resulted in higher oil content than Hysun-33. The interaction of seed priming with 0.2% $ZnSO_4$ x geometry of 85 x 20 cm gave highest oil content. The higher oil content with zinc priming may be attributed to active role of zinc for several enzymes (Rehman et al., 2015). Shinde and Gautam (2016) suggested significant effect of planting densities on sunflower oil content.

Conclusions and Recommendations

The results suggested that seed primed with 0.2% $ZnSO_4$ and planted as 85 x 20 cm conferred higher growth, better yield components that resulted higher yield and oil content of sunflower. The variety HO-1 is best option to yield as compared to another available hybrid Hysun-33.

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Novelty Statement

The present research work investigated the effect of seed priming with $ZnSO_4$ and planting geometry on growth and yield of sunflower, which could help in obtaining quality seed in the local conditions.

Author's Contribution

ZAA planned experiment, gathered data and prepared manuscript. MNK guided scholar as a whole from designing experiment to writing of manuscript. AAS provided research facility and helped in manuscript write-up. NL contributed in research material and data analysis. MIK helped in interpretation of results and editing of manuscript. ANS contributed in collection of data and proof reading of manuscript. MBA helped in tabulation and correction of manuscript.

Conflict of interest

There is no conflict of interest among authors.

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