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Research Article

Intercropping Sunflower with Mungbean for Improved Productivity and net Economic Return under Irrigated Conditions

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Abstract | Increasing population and decreasing on farm resources are threating the future food security. In this scenario, the cropping systems which can meet the increasing demand of food, feed and forage are needed. Intercropping is an eco-friendly option for sustaining and increasing the productivity of farmlands. Therefore, a field study relating to sunflower-mungbean intercropping intensities under irrigated conditions was conducted at Agronomic Research Farm, University of Agriculture, Faisalabad during the spring season, 2014 in RCB design with triplicate run. The treatments included viz. Four sunflower plants m^{-2} + 30 mungbean m^{-2}, 6 sunflower plants m^{-2} + 30 mungbean plants m^{-2}, 8 sunflower plants m^{-2} + 30 mungbean plants m^{-2}, 4 plants m^{-2} of sunflower alone, 6 plants m^{-2} of sunflower alone, 8 plants m^{-2} of sunflower alone and 30 plants m^{-2} of mungbean alone. Plant population was maintained by keeping 75 cm apart single rows of sunflower and 50 cm apart double rows of mungbean both in sole and in the intercropped plots. The results indicated that sole sunflower grown in the pattern of 6 sunflower plants m^{-2} produced significantly higher achene yield than rest of the planting patterns under study. As regard sunflower-mungbean intercropping system all intercrops gave more economic returns than sole cropping of sunflower and mungbean and planting 6 sunflower plants + 30 mungbean plants m^{-2} proved to be superior with respect to grain yield and net economic return per unit area. Sunflower appeared to be dominant crop as was indicated by its higher values of competitive ratio and positive sign of aggressivity. However, on the basis of land equivalent ratio, maximum yield advantage was recorded in in 4 sunflower plants m^{-2} + 30 mungbean plants m^{-2} intercropping system. These results suggested that farmers may adopt 6 sunflower plants m^{-2} + 30 mungbean plants m^{-2} in intercropping system for increased productivity and economic return.

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Introduction

Sunflower *(Helianthus annuus* L.) an important oilseed crop belongs to the family composite. Sunflower oil is quite palatable containing soluble vitamins A, D, E, K and 40 to 47% oil content (Saleem et al., 2003). Its seed contains 23% protein, 40-50 % oil that is free from toxic elements. Its oil contains 110 g

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kg^{-1} of saturated fatty acids, 4-9% palmitic acid, 1-7% stearic acid, 14-40% oleic acid and 48-74% linoleic acid (Hatim and Abbasi, 1994; Rodriguez et al., 2002). Its oil is called premium oil because it contains high percentage of polyunsaturated fatty acid (60%) and it has been accepted that higher level of unsaturated fatty acid in the diet reduces the level of blood cholesterol which is responsible for heart diseases (Rathore, 2001).

Intercropping being a unique property of tropical and sub-tropical areas is becoming popular day by day among small farmers as it offers the possibility of yield advantage relative to sole cropping through improved and stable yield (Bhatti et al., 2006). Potential of raising other crops such as forage legumes and non-legumes in association with major staple food crops like rice could be substantially enhanced through intercropping (Saeed et al., 1999a). It also helps maintaining the soil fertility, making efficient use of nutrients (Maingi et al., 2001), ensuring economic utilization of land, labor and capital (Jeyabal and Kuppuswamy, 2001) and controlling pest's population (Epidi et al., 2008).

Intercropping can help in increasing crop productivity particularly at small farms of Pakistan. However, conventional planting geometry does not permit convenient intercropping. There is dire need to search a new pattern of sunflower plantation that can give sunflower yields compatible with that of the conventional plantation and also facilitates intercropping. Non-uniform plant distribution exhibits a remarkable effect on the productivity of the crop. Uniform adjustment of the crop spacing in the field is one of the most important factors for yield and quality of sunflower (Barros et al., 2004). Four plant spacing (20, 25, 30 and 35 cm between hills) in sunflower revealed that plant height, stem diameter, head diameter, number of seeds per head, 1000-seed weight and seed yield (kg ha^{-1}) were significantly affected by plant spacing. Twenty-five cm was observed as suitable plant spacing, whereas higher or lower plant spacing had a negative effect on seed and oil yields ha^{-1} (Thabet, 2006).

Various crops have either synergistic or antagonistic effects when grown simultaneously. Intercropping of legume crops are beneficial to small land holders in which they can get maximum profit in cheaper way. Recent research has shown substantial yield advantages of intercropping of different crops. Consequently, the present study was planned to determine the bio-economics of component crop sunflower based intercropping system. Keeping in view the above facts, the objectives of these studies were as follows:

- To explore the best planting pattern for sunflower yield which facilitate intercropping without loss in yield under the prevailing conditions.
- To estimate the economic benefits and sustainability of sunflower intercrop with mungbean.

Materials and Methods

A field experiment pertaining to studies on sunflower-mungbean intercropping intensities under irrigated conditions was conducted at Agronomic Research Farm, University of Agriculture, Faisalabad, Pakistan during Autumn 2014. Experiment was laid out in randomized complete block design with three replications. Plot size was 4.5 m × 8 m. The treatments included viz. 4 sunflower plants m^{-2} + 30 mungbean m^{-2}, 6 sunflower plants m^{-2} + 30 mungbean plants m^{-2}, 8 sunflower plants m^{-2} + 30 mungbean plants m^{-2}, 4 plants m^{-2} of sunflower alone, 6 plants m^{-2} of sunflower alone, 8 plants m^{-2} of sunflower alone and 30 plants m^{-2} of mungbean alone. Plant population was maintained by keeping 75 cm apart single rows of sunflower and 50 cm apart double rows of mungbean both in sole and in the intercropped plots. Mungbean variety Azri-2006 and sunflower hybrid Hysun-33 was used in the experiment. Mungbean and sunflower with same planting intensities were sown as a sole crop for determining the land equivalent ratio (LER).

All the cultural practices were kept uniform during study. Plant height, 1000 achene weight, achene yield, harvest index and protein contents were recorded for sunflower crop while Plant height, No. of seeds per pod, 1000 grain weight, grain yield, harvest index and protein contents for mungbean were recorded according to standard procedures. Harvest index (HI) and different competition functions were calculated by the following formulae:

$$Harvest\ Index = \frac{Grain\ Yield}{Biological\ Yeild} \times 100$$

$$LER = LER\ (Sun) + LER\ (Mung)$$

$$LER\ (Sun) = \frac{Grain\ yield\ of\ intercropped\ Sun}{Grain\ yield\ of\ sole\ sunflower}$$

$$LER\ (Mung) = \frac{Grain\ yield\ of\ intercropped\ mung}{Grain\ yield\ of\ sole\ mung}$$

$$\text{Net Return} = \text{Total Income} - \text{Total Cost}$$

$$Aggressivity = \frac{Yab\ Yba}{Yaa \times Zzb\ Ybb \times Zba}$$

Where;
Yab: Aggressivity value for component crop "a"; Yaa: Pure stand yield of crop "a"; Yab: Intercrop yield of crop "a"; Ybb: Pure stand yield of crop "b"; Yba: Intercrop yield of crop "b"; Sun: Sunflower; Mung: Mungbean.

Results and Disscussion

Plant height: The data in Table 1 shows the effect of planting intensity and intercropping on plant height and it was found to be non-significant. The maximum plant height was measured (182.35 cm) in case of intercropping of sunflower with mungbean and minimum height of 176.36 cm in sunflower alone; however, these differences could not reach to the level of significance. The possible reason for almost same height in all the treatment is that all the plants have an equal opportunity of the resources especially of light in intercropping. Another important reason for these types of results is that sunflower plant height is mainly controlled and regulated by the genetic rather than various intercropping and planting technique. The results are in line with Sultana (2007) and Ahmad (2001) who also reported non-significant differences among planting geometry for plant height. The results are in contrast with Panhwar et al. (2004) who reported significant differences for maize plant height among maize-soybean intercropping and plant spacing. Bhatti (2005) also observed significant effect of plant height in case of sesame-soybean intercropping under different plant spacing.

1000-achene weight: 1000-achene weight is one of the important factors that play a vital role in the final yield of a crop. The data related to sunflower 1000-achene weight (Table 1) depicted that the maximum 1000- achene weight of 42.85 g was noted when sunflower was sown at4 plants m^{-2} + 30 plants m^{-2} of mungbean (T2) while minimum achene weight (36.01 g) was observed where sunflower sown at 8 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean (T3). The maximum 1000-achene weight (42.85 g) was found when sunflower sown alone with minimum of 36.01 g in intercropping of sunflower with mungbean. Malik et al. (1992) findings are similar with this result who found significant effect of planting pattern on sesame grain weight. The result is in contrast with Saleem et al. (2003) who found no differences among the mean of weight in case of planting patterns. The differences in the results can be attributed to differences in the climatic condition, fertility status of soil and genetic makeup of crop plants.

Achene Yield: The data related to achene yield is presented in the Table 1 showed that the highest achene yield of 2855 kg ha^{-1} was obtained in case of alone sunflower followed by the yield of 2741 kg ha^{-1}. However in case of intercropping maximum yield was 2557 kg ha^{-1}. The reduction of yield in intercropping probably may be due to inter and intraspecific competition for light, moisture, space and nutrients etc. The results are

Table 1: *Performance of sunflower as affected by planting intensities and intercropping systems.*

Intercropping system	Height (cm)	1000 achene weight(g)	Achene yield (kg/ha)	Harvest index (%)	Protein contents (%)
T_1 (4 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	182.35	39.82 c	1990 f	23.16 c	20.35
T_2 (6 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	180.23	39.47 cd	2557 c	27.13 ab	18.86
T_3 (8 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	177.02	36.01 e	2448 d	23.50 c	19.90
T_4 (4 plants m^{-2} of sunflower alone)	176.36	42.85 a	2192 e	24.92 bc	21.25
T_5 (6 plants m^{-2} of sunflower alone)	179.2	41.97 b	2855 a	27.92 a	19.93
T_6 (8 plants m^{-2} of sunflower alone)	180.69	38.95 d	2741 b	26.72 ab	20.78
LSD	NS	0.62	54.7	2.59	NS

in line with that of Zaman and Maity (1988) and Khan (2001). The present results are in consistent with the results of Panhwar (2004) who found significant effect of grain yield in case of maize-soybean intercropping under different plant spacing and nitrogen levels. Bhatti (2005) also found mean differences among intercropping, planting geometry and their interaction in sesame-legume intercropping under different planting geometry. The data Ullah et al. (2007) indicated significant differences among various planting patterns, intercropping system and treatment combinations. Khakwani (2001) revealed that relaying of canola in sunflower did not affect sunflower yield significantly.

Harvest Index: The efficiency of a crop to convert the dry matter into the economic yield is determined with the help of harvest index value. More the value of harvest index of a variety more is the efficiency of the variety to convert the dry matter into the economic part of the crop. The data depicting the harvest index of sunflower is given in Table 1 which shows that intercropping has significant effect on the harvest index. Greater harvest index of 27.92% was obtained when sunflower sown alone (6 plants of sunflower m^{-2}) and lower harvest index of 27.13% in case of sunflower intercrop with mungbean (6 sunflower plants $m^{-2}$and 30 mungbean plants m^{-2}). The results are in line with the results of Saleem et al. (2003) who found significant effect of both these factors on harvest index. Bhatti (2005) however noticed no effect of intercropping and row spacing on sesame harvest index.

Protein Content: Protein content is also an important factor of sunflower with reference to nutrition. The data related to the protein content is presented in Table 1. The table shows that protein content of sunflower is significantly affected by the intercropping of sunflower with mungbean. The higher protein content of 21.25 % was measured in case of sunflower sown alone and lower protein content (20.35%) in the treatment when sunflower intercropped with mungbean.

Performance of mungbean in sunflower-mungbean intercropping

Plant height: The results of mungbean plant height are presented in Table 2. It shows significant effect of intercropping intensities on the plant height. The higher plant height (49.6 cm) was found when mungbean was sown alone at 30 plants m^{-2}. But in case of intercropping, maximum plant height (35.3 cm) was measured in 4 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean (T_1) which was statistically at par with T_2 (6 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean) and T_3 (8 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean). The results were similar to those of Bhatti (2005) who found significant effect of intercropping and planting patterns on plant height.

Number of seed per pod: Number of seeds per pod is one of the main yield contributing parameters in case of legumes. Significant effect of planting intensities and intercropping on the number of pods per plant was depicted by the table. The greater number of seeds per pod (7.83) was found when mungbean was sown alone at 30 plant m^{-2}. The results are contrary to Bhatti (2005) where intercropping of sesame with mungbean under different planting spacing showed non-significant effect on seeds per pods.

1000-grain weight: The Table 2 shows significant effect of intercropping on the 1000-grain weight. The highest 1000-grain weight (44.88 g) was found when mungbean was sown alone at 30 plants m^{-2}. As far as intercropping were concerned T_1 (4 sunflower plants $m^{-2}$and 30 mungbean plants m^{-2}) gave 43.66 g,

Table 2: *Performance of mungbean as affected by planting intensities and intercropping systems.*

Intercropping system	Height (cm)	Number of seeds per pod	1000 grain weight(g)	Grain yield (kg/ha)	Harvest index (%)	Protein contents (%)
T_1 (4 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	35.3 b	7.16 b	43.66 b	716.92 b	25.65 b	6.5 b
T_2 (6 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	34.52 b	6.53 bc	42.06 c	559.98 c	21.22 b	5.3 c
T_3 (8 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	32.6 b	5.67 c	40.46 d	427.40 c	23.41 b	5.1 c
T_7 (30 plants m^{-2} of mungbean alone)	49.6 a	7.83 a	44.88 a	983.98 a	31.98 a	7.3 a
LSD	3.18	1.39	0.55	52.56	6.16	0.47

the maximum weight while the minimum (40.46 g) 1000-grain weight was observed in case of 8 plants m^{-2} along with mungbean (T_3). The results are similar to Sahi (1988) and Nishat (1989) showing significant effect on lentil 1000-grain weight in wheat-lentil intercropping.

Grain Yield: Data (Table 2) showed highly significant effect of intercropping intensities on the grain yield. Maximum grain yield 983.98 kg ha^{-1} was found when mungbean was sown alone at 30 plants m^{-2}. But as far as intercropping with different intensities is concerned maximum grain yield of 716.92 kg ha^{-1} was measured in T_1 (4 plants of sunflower m^{-2} + 30 plants of mungbean m^{-2}) followed by T_2 559.98 kg ha^{-1} (sunflower sowing at 6 plants m^{-2} in mungbean intercropping) while the minimum grain yield (427.40 kg ha^{-1}) was obtainedin case of T_3 (8 sunflower plants $m^{-2}$and 30 mungbean plants m^{-2}) Different suppressive effects of intercropping on various yield components of intercropping on various yield components of mungbean grown under different planting intensities may be due to shading effects of sunflower on lower canopy of legume and interspecific competition between mungbean and sunflower. Ahmad and Rao (1982), Vyas et al. (1995), Bhatti (2005) and Rao (1991) also described the significant effect of intercropping on mungbean grain yield.

Harvest index: The data related to mungbean harvest index (%) presented in (Table 2) show that intercropping along with different planting intensities has significant effect on harvest index.

However, the maximum harvest index (31.98%) was found in T_1 when mungbean was sown at 30 plants m^{-2} alone and minimum harvest index was measured (21.22%) when 30 plants m^{-2} mungbean was sown with 6 plants of sunflower m^{-2}. The results are in line with Sultana (2007) who found significant of harvest index in sunflower-mungbean intercropping. Bhatti (2005) also narrated significant effect of intercropping and planting patterns on mungbean harvest index.

Protein Content: In case of legumes protein content is an important parameter with regards to nutritional value of the grain. Data show (Table 2) that the maximum protein content of 7.3% was found when mungbean was sown alone at 30plants of mungbean m^{-2}. But in case of intercropping with different planting intensities maximum protein contents (6.5%) was measured in 30 plants of mungbean m^{-2} + 4 plants of sunflower m^{-2} and minimum protein content (5.1%) was found in 8 plants of sunflower m^{-2} + 30 plants of mungbean m^{-2}. The results are in contrast with Bhatti (2005) who described non-significant effect of protein contents in sesame-mungbean intercropping under different planting spacing.

Sunflower achene yield equivalent

Sunflower achene yield equivalent was computed by converting the yield of intercrop into the achene yield of sunflower, based on existing market price of each crop. It is one of the important criteria used for the assessing the intercropping advantages over monocropping. Sunflower achene yield equivalent of all planting geometry was higher than the yield of sunflower alone (Table 3). Maximum sunflower achene yield (2970.6 kg ha^{-1}) was recorded when sunflower and mungbean sown in association at 6 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean and minimum (2192 kg ha^{-1}) sunflower achene yield was recorded in 4 plants m^{-2} of sunflower alone treatment. The differences in yield equivalent were due to the variation between the prices of the crop and their yield at different planting geometry. The results are similar to those of Bhatti (2005) and Sarkar and Chauhdhary (2000), who reported a remarkable increase in Sunflower achene yield equivalent due to intercropping and planting pattern.

Table 3: *Sunflower achene yield equivalent (kg ha^{-1}) as affected by planting intensities and intercropping systems.*

Intercropping system	Sunflower Yield (kg ha^{-1})	Mungbean Yield (kg ha^{-1})	Sunflower Yield equivalent (kg ha^{-1})	Total Sunflower Yield equivalent (kg ha^{-1})
T_1 (4 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	1990	716.92	529.6	2519.6
T_2 (6 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	2557	559.98	413.6	2970.6
T_3 (8 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	2448	427.4	315.6	2763.6

Land Equivalent Ratio (LER): Land equivalent ratio is the relative area of sole crop required to produce the yield achieved in intercropping (Khan et al., 1988). In determining the land equivalent ratio, it is stipulated that management practices for sole and intercropping crops are same.

Table 4: *Land Equivalent Ratio (LER) as affected by planting intensities and intercropping systems.*

Intercropping system	Sunflower	Mungbean
T_1 (4 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	0.91	0.73
T_2 (6 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	0.90	0.57
T_3 (8 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	0.89	0.43

Table 5: *Competitive Ratio (CR) as affected by planting intensities and intercropping systems.*

Intercropping system	Sunflower CR_S	Mungbean CR_M
T_1 (4 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	71.89	0.01
T_2 (6 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	39.34	0.03
T_3 (8 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	28.56	0.04

The LER values for different planting intensities (Table 4) show that land equivalent ratio values are higher than one in all planting intensities which indicate the advantages of intercropped over the sole cropping of sunflower. The maximum LER value of 1.64 was obtained when sunflower sown at 4 plants m^{-2} which showed 64% yield advantages. In other words it is possible to harvest the sunflower yield from one hectare of intercropping that is harvestable from 1.64 hectare of sunflower alone cultivation. The minimum LER value (1.33) was obtained at 8 plant m^{-2} sowing with mungbean intercropping. Higher land equivalent ratio in intercropping at various planting intensities was described by the better utilization of the natural (light, land) and added (fertilizer, water) resources. Bhatti (2005), Sarkar and Chakraborty (2000) and Sarkar and Sanyal (2000) also reported the higher LER value for intercropped than sole cropping in sesame intercropping with mungbean.

Competition Functions: Competition behavior of component crops across various planting intensities in intercropping was determined by competitive ratio and aggressivity.

Competition Ratio (Cr): Competition ratio is an important competitive function to determine the degree with one crop competes with other crop. The Table 5 shows the CR value of sunflower under different planting intensities. The higher CR value for sunflower in all planting intensities showed that sunflower is more competitive than mungbean in all planting geometries. The highest CR value was observed at 4 plants m^{-2} of sunflower along with 30 plants m^{-2} of mungbean followed by 6 plants m^{-2} of sunflower sowing in association with mungbean. It is similar to the results of Bhatti (2005), El-Edward et al., (1985) and Sarkar and Chakraborty (2000).

Aggressivity Value

Table 6 shows the degree of dominance of one crop over the other when sown together. It is an important value to determine the competitive ability of a crop growing in association with each other. If value of aggressivity is zero, then it means that cops have no competition for each other. In case of any value, both the crops have the numerical value with opposite sign. Positive sign shows the dominancy or vice versa. The greater the numerical value bigger will be the differences in crops competition and higher will be differences in expected and actual yield.

Table 6: *Aggeressivity value (A) for the component crops as affected by planting intensities and intercropping systems.*

Intercropping system	Sunflower A_S	Mungbean A_M
T_1 (4 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	1.52	-6.89
T_2 (6 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	1.63	-4.36
T_3 (8 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	1.68	-3.19

Sunflower did not compete equally with mungbean under different planting patterns. Regardless of the planting intensities, the positive sign of sunflower for 'A' values indicated the dominant behavior of sunflower over mungbean in all treatments. The minimum value of 1.52 in 4 plants m^{-2} sunflower planting with mungbean showed that sunflower at this planting geometry had less competition with mungbean. Sarkar and Sanyal (2000), Bhatti et al. (2006) and

Sarkar and Chakraborty (2000) also reported similar type of results.

Economic analysis

The details of economic analysis is given in the Table 7 Different intercropping intensities resulted in different income (Rs. ha-1) as indicated in the table. Treatment in which sunflower was sown at 6 plants m^{-2} of sunflower intercropped with 30 plants of mungbean m^{-2} resulted in highest net income of Rs. 140384, while 30 plants m^{-2} of mungbean alone while the minimum net income of Rs. 34541.

Table 7: *Competitive Ratio (CR) as affected by planting intensities and intercropping systems.*

Treatments	Gross income (Rs.)	Gross cost (Rs.)	Net return (Rs.)
T_1 (4 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	156408	36930	119478
T_2 (6 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	177314	36930	140384
T_3 (8 plants m^{-2} of sunflower + 30 plants m^{-2} of mungbean)	162635	36930	125705
T_4 (4 plants m^{-2} of sunflower only)	120560	30780	89780
T_5 (6 plants m^{-2} of sunflower only)	157025	30780	126245
T_6 (8 plants m^{-2} of sunflower only)	150755	30780	119975
T_7 (30 plants m^{-2} of mungbean only)	64451	29910	34541

Conclusions

Intercropping system reduced the grain yield. However, additional production obtained from sunflower + mungbean intercrop compensated more than the losses in sunflower production. Planting intensities had significant effect on grain yield and 1000 grain weight. Maximum LER was recorded in sunflower planted at 4 plants m^{-2} and intercropped with mungbean. Maximum net farm income was obtained from sunflower planted at 6 plants of sunflower m^{-2} intercropped with mungbean. intercropping of 30 plants of mungbean and 6 plants of sunflower in one m^{-2} proved to be feasible as well as convenient for farm operations.

Author's Contribution

Muhammad Anas and Raza Ullah conducted experiment and collected data. Abdul Jabbar conceived the idea and supervised the experiment. Muhammad Aqeel Sarwar wrote abstract, introduction and provided technical input at every step. Muhammad Khubaib Abuzar did statistical analysis. Ijaz Ahmad and Sohail Latif wrote the remaining article.

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