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WHEAT GENOTYPES POTENTIAL WITH LONGEST COLEOPTILE LENGTH SOWN AT DIFFERENT SOWING DEPTHS

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Abstract

Southern districts of Khyber Pakhtunkhwa, Pakistan are considered arid and rain-fed because of low annual rainfall. Moisture levels in many parts of this zone are deeper causing poor seed germination. To overcome this problem, ten wheat genotypes having variable coleoptile length were evaluated and tested at three sowing depths. Genotypes included in the studies were; NIFA-Insaf, NARC-09, Pakistan-13, Bathoor-2008, Shahkar-2013, Shalkot, AARI-2008, Gandum-1, Tatara and Local Bhakkar. All the genotypes were tested at 5 cm, 10 cm and 15 cm of sowing depths. Studies were carried out in pots having 0.61 m^2 area only two lifesaving irrigations with measured quantity of water (two liters) were given to all pots. Genotype NIFA-Insaf, followed by Shahkar-2013 and Shalkot performed best by showing maximum percent germination, highest 1000-grain weight, maximum fertile tillers, maximum grains $spike^{-1}$, highest biological and grain yield. Results further revealed that sowing at 10 cm depth; the wheat genotypes produced largest number of fertile tillers, grains $spike^{-1}$ and eventually the enhanced grain yield. Planting wheat at 15 cm of depth adversely affected the yield and all other yield contributing parameters. Current findings found that wheat variety NIFA-Insaf by having longer coleoptile length, performed best at deeper sowing with low moisture availability.

Key words: Wheat genotypes, Coleoptile length, Sowing depth, Yield components, Grain yield.

Introduction

In Pakistan the total area under wheat crop is about 8.825 million hectares producing about 24. 946 million metric tons each year (Anon., 2020). Out of 8.7 million hectares 4.8 million hectares of wheat is cultivated in rainfed areas of the country. Whereas 60% of this rain-fed area under wheat is cultivated in Khyber Pakhtunkhwa province of Pakistan. Dera Ismail Khan District is one of the largest areas of province where wheat is grown in irrigated as well rainfed conditions. The rainfed area of the Dera Ismail Khan is known as 'Daman' which is characterized by low yield and severe water shortage causing larger area of lands to be unproductive. Wheat-growing season in this area depends on rains during germination and crop establishment and grain filling. Scientists of the area are always busy to introduce new high yielding wheat varieties resistant to climatic adversities especially drought. Seed germination, vigor and coleoptile length are fundamentals for the establishment of crop plants in that rainfed area. The rate and degree of seedling establishment are extremely important factors to determine the time of maturity and grain yield (Rauf *et al*., 2007).

Improvement in wheat production can be brought by evaluating germplasm having genetic variation which provides the strong base for breeding program (Zeb *et al*., 2009). Rebetzke *et al*., (2007), and Yagmur & Kaydan (2009) studied various aspects of wheat and reported that moisture along with mineral nutrients transportation can be affected by the seeding depth and play an important role in growth and yield improvement by controlling source-sink relationship. Lack of moisture in upper zone of soil usually delays planting and reduces grain yield of wheat crop by decreased germination percentage. The short coleoptiles of semi-dwarf wheat varieties reduce emergence when sowing depth is more than 5 cm. Since the area under study is dry and arid with soil surface, most of the time dry, but moisture is available deeper in the soil than the normal seeding zone. Deeper than normal sowing by planting seed in this moisture zone can help seed germinate easily and establish the crop properly. However few of wheat cultivars would emerge from depth better than others due their genetic makeup. Wheat production in areas where moisture availability is always a problem can be improved by evaluating and selection drought tolerant strains or varieties (Ahmad *et al*., 2013). Deeper sowing is advised in area having rainfall lower than optimum to enable the seed to get to the zone of moisture level for better germination. Deep sowing could ensure adequate seed-zone moisture before germination and thereby enhance seedling establishment (Mohan *et al*., 2013). A significant effect of sowing depth of wheat on yield and yield contributing parameters has been reported by Alam *et al*., (2014). Few other have reported that seeds sown at deeper than normal significantly reduces seedling emergence, crop establishment and yield (Aikins *et al*., 2006 and Mohan *et al*., 2013). Keeping all that in view, it seemed necessary to evaluate wheat germplasm having diverse genetic makeup at variable plating depths in soil types exist in this area to select best wheat material and optimum planting depth that can improve seed germination and establish crop with better grain yield.

Materials and Methods

The experiment was designed and carried out in pots having size of 0.61 m^2 area. Clay loam soil of fine texture was prepared to fill the pots. Experiment was conducted in a completely randomized design (CRD) with two factors having ten wheat genotypes in Factor-A while three sowing depths were maintained in Factor-B. Genotypes selected for this study were NIFA-Insaf, NARC-09, Pakistan-13, Bathoor-2008, Shahkar-2013, Shalkot, AARI-2008, Gandum-1, Tatara and Local Bhakkar. Each pot contained four hills having three seeds per hill. Two lifesaving irrigations with measured quantity of water (two liters) were given to all pots due to lack of rainfall.

Data recorded: By using the standard procedure, the data were recorded on the traits seed germination, time to germination, SPAD values, plant height, number of fertile tillers, spike length, number of grains per spike, 1000-grain weight, grain yield and biological yield respectively.

Statistical analysis

All the data were analyzed according to the analysis of variance (Steel *et al.,* 1997), while the treatments were compared and separated by using LSD test (Black, 2011). The statistical analysis was done at 5% level of probability through computer software package "Statistix 8.1".

Results and Discussion

Seed germination: Germination is an important parameter that could be used to investigate the effects of planting depths. Data collected for seed germination in various wheat genotypes planted at various depths during first year of study are presented in Table 1. It was observed that maximum percentage of germination was recorded for the two genotypes i.e., NIFA-Insaf and Gandum-I that revealed 85.18% and 81.48% seed germination, respectively. The genotype Bathoor-2008 showed the poor results by having only 67.00% of seed germination. Rest of the genotypes resulted in statistically similar percentage of seed germination. Looking in the effect of planting depths it was observed that planting the seed at the shallowest depth (5 cm) resulted in maximum germination (80.97%), followed by 76.93% with 10 cm sowing depth. The poorest germination (72.21%) was recorded in wheat with 15 cm depth.

During second year, the studies revealed non-significant differences among various wheat genotypes for seed germination. However, genotype NIFA-Insaf was at the top by having 82.51% of seed germination. Results obtained during second year of study revealed that the highest seed germination (80.96%) was recorded when seeds were sown at shallowest planting (5 cm depth) while deepest sowing resulted in minimum germination (70.08%).

Interaction between the two factors for seed germination was found non-significant during both years. However, the genotype NIFA-Insaf showed better performance at all the three depths. Although percent germination was less when planted at 15 cm depth but still it was better than all other genotypes and showed maximum germination at deeper planting. Keshtkar *et al.*, (2009), Amram *et al*., (2015) and Kong *et al*., (2016) also reported that wheat germination always decreases as sowing depth increases, and the same findings also observed in the present studies. Similarly the current findings suggested that genotypes with longer coleoptile showed better germination during both years of study. NIFA-Insaf and NARC-09 with longer coleoptile were reported as the best genotypes by having maximum germination percentage. Although other factors may affect the emergence, however, the coleoptile length must be taken into account for wheat cultivation in areas with deeper moisture levels (Rebetzke *et al*., 2007). Alam *et al*., (2021) mentioned that the coleoptile length determines the ability of wheat seed to emerge from depth.

Time to germination: Although deeper planting of wheat delayed the germination significantly both years however differences among the genotypes for time taken to germination was found non-significant statistically during first year while significant during second year of study (Table 1). The data recorded during the second year of study revealed that Bathoor-2008 took minimum days to germination but it was found at par with most of the genotypes tested. The genotype 'Tatara' was found to be the slowest one and took 10.22 days to germination. Looking into the results obtained for effects of planting depths it was found that germination was delayed at deeper sowing. Sowing at 5 cm of depth took minimum time i.e. 7.63 and 8.13 days to germination during first year and second year of study, respectively. Interaction between the two factors was found significant both years. Minimum time noted to germination was 6.00 and 6.66 days for genotypes Shahkaar-13 and NIFA-Insaf, respectively during the first year when planted at 5 cm of depth. While it was 5.00 days for Shahkar-13 in first year and same time i.e. 6.66 days for NIFA-Insaf during second year of study at same depth of 5 cm. Maximum time to germination during the first year i.e. 11.66 days was taken by genotype 'NARC-09' when planted at 15 cm of depth while it was even longer i.e. 12.00 days for same genotype and same depth during second year of study. It was observed during the current study that germination time can be significantly different for different genotypes at various sowing depths. Light conditions on the surface and water availability around seed limit the emergence of seeds on the soil surface (Chachalis & Reddy, 2000). It has been reported by Thomas *et al*., (2006) might be attributed to the limited carbohydrate reserves. Benvenuti *et al*., (2001) stated that seed emergence and succeeding growth competition are the major disadvantages of planting seeds deeper than normal.

SPAD values: SPAD value is an indicator for chlorophyll content in the leaves. Highest SPAD value of 55.79 was recorded for genotypes NIFA-Insaf (Table 2) followed by 49.91 (Shalkot) and 47.31 (Shahkar-2013). Pakistan-13 and Gandum-1 revealed 43.39 and 40.56 SPAD value, respectively. Statistically similar SPAD value was recorded for NARC-09 and Tatara with 38.64 and 38.45, respectively. The genotype Local Bhakkar was found to be the poorest one having SPAD values of 33.56. Looking into the data recorded for effect of sowing depth on SPAD value showed that planting wheat at 10 cm depth revealed significantly higher SPAD values of 45.09, followed planting at 5 cm depth with SPAD value of 42.24. Planting wheat at 15 cm of depth adversely affected the chlorophyll content with lowest SPAD values (38.03). Almost similar trend was observed during second year with NIFA-Insaf having best ability to show highest SPAD values followed by Shalkot and Shahkar-2013. Interaction between the two factors for SPAD value was found significant statistically both years. Results presented in Table 2 reveal that the genotype 'NIFA-Insaf' as showed best SPAD value (56.94) when planted shallowest and this genotypes showed best performance when planted at deeper sowing as well. The same trend was observed both years. Bhatoor-2008, AARI-2008 and Local Bhakkar were found the poorest ones and showed minimum SPAD value at all planting depths in first year. Bhatoor-2008 and Tatara were at the bottom during second year of study minimum values of SPAD. Kilic and Yağbasanlar (2010) reported a positive relationship between chlorophyll content in the leaves and other parameters including grain yield. Similar trend has been observed in the current studies with a positive relationship of chlorophyll content, grain yield and sowing depth.

Table 1. Seed germination rate (%) and days to emergence of various wheat genotypes as influenced by variable planting depth.

Genotypes (G)	Seed germination rate (%)[1]		Days to emergence[2]	
	Year-1	Year-2	Year-1	Year-2
1. NIFA-Insaf	85.18 a	82.51 NS	8.77 NS	9.55 abc
2. NARC-09	74.29 ab	77.07	8.55	9.33 abc
3. Pakistan-13	79.85 ab	72.33	8.22	9.55 abc
4. Bathoor-2008	67.00 b	71.51	8.00	8.22 c
5. Shahkar-2013	80.55 ab	77.18	7.66	8.55 bc
6. Shalkot	77.89 ab	76.96	8.66	10.44 a
7. AARI-2008	72.66 ab	69.66	7.66	9.66 abc
8. Gandum-1	81.48 a	78.00	8.33	9.00 abc
9. Tatara	73.71 ab	75.55	8.00	10.22 a
10. Local Bhakkar	74.41 ab	77.29	9.44	10.11 ab
Sowing depth (SD)				
1. 5 cm	80.97 a	80.96 a	7.63 b	8.13 c
2. 10 cm	76.93 ab	76.37 a	8.20 b	9.70 b
3. 15 cm	72.21 b	70.08 b	9.16 a	10.56 a
G X SD				
1X1	88.89 NS	86.11 NS	6.66 ab	6.66 c-f
2X1	78.11	80.55	7.00 ab	6.33 def
3X1	83.33	78.11	7.66 ab	9.00 a-e
4X1	70.11	75.33	8.33 ab	8.66 b-f
5X1	86.11	83.33	6.00 b	5.66 f
6X1	80.55	83.33	7.66 ab	9.00 a-e
7X1	80.55	77.77	8.00 ab	9.00 a-e
8X1	86.11	83.33	7.66 ab	8.66 b-f
9X1	78.14	80.89	8.66 ab	9.00 a-e
10X1	77.76	80.89	8.66 ab	9.33 a-d
1X2	86.11	83.33	9.66 ab	10.33 ab
2X2	72.55	78.11	8.00 ab	9.66 abc
3X2	80.89	72.22	8.00 ab	8.66 b-f
4X2	69.44	72.22	9.33 ab	10.00 ab
5X2	80.55	78.11	7.00 ab	9.00 a-e
6X2	78.11	75.33	8.33 ab	11.00 ab
7X2	72.89	72.55	6.66 ab	9.00 a-e
8X2	80.55	78.11	8.00 ab	9.00 a-e
9X2	72.89	75.67	8.00 ab	10.66 ab
10X2	75.36	78.11	9.00 ab	9.66 abc
1X3	80.55	78.11	10.00 ab	11.66 ab
2X3	72.22	72.55	10.66 a	12.00 a
3X3	75.33	66.66	9.00 ab	11.00 ab
4X3	61.44	67.00	9.33 ab	6.00 ef
5X3	75.00	70.11	10.00 ab	11.00 ab
6X3	75.00	72.22	10.00 ab	11.33 ab
7X3	64.55	58.66	8.33 ab	11.00 ab
8X3	77.77	72.55	9.33 ab	9.33 a-d
9X3	70.11	70.11	7.33 ab	11.00 ab
10X3	70.11	72.89	10.66	11.33 b

1. $LSD_{0.05}$- First year: G: 13.94 SD: 5.58 G X SD: NS. Second Year: G: 13.94 SD: 5.58 G X SD:
2. $LSD_{0.05}$: First Year: G: NS, SD: 0.79, G X SD: 4.10. Second Year: G: 1.57 SD: 0.63 G X SD: 3.26

Table 2. SPAD value and plant height of various wheat genotypes as influenced by variable planting depth.

Genotypes (G)	SPAD values[1]		Plant height (cm)[2]	
	Year-1	Year-2	Year-1	Year-2
1. NIFA-Insaf	55.79 a	49.96 a	74.74 a	62.75 a
2. NARC-09	38.64 ef	34.61 ef	65.50 b	55.79 b
3. Pakistan-13	43.39 d	38.85 d	66.14 b	53.81 bc
4. Bathoor-2008	36.60 f	32.77 fg	61.38 c	50.02 d
5. Shahkar-2013	47.30 c	42.36 c	65.29 b	55.69 b
6. Shalkot	49.91 b	44.69 b	66.74 b	56.13 b
7. AARI-2008	34.21 g	30.63 gh	64.46 bc	53.88 bc
8. Gandum-1	40.05 e	35.86 e	65.20 b	56.09 b
9. Tatara	38.45 ef	34.44 ef	61.23 c	51.31 cd
10. Local Bhakkar	33.56 g	30.05 h	74.31 a	64.00 a
Sowing depth (SD)				
1. 5 cm	42.24 b	37.83 b	67.77 b	57.11 b
2. 10 cm	45.09 a	40.39 a	71.10 a	60.19 a
3. 15 cm	38.03 c	34.05 c	60.63 c	50.55 c
G X SD				
1X1	56.91 ab	50.96 ab	74.63 abc	63.09 abc
2X1	39.59 g-l	35.46 g-l	68.96 b-e	57.75 cde
3X1	44.09 efg	39.48 efg	67.92 c-f	55.30 d-h
4X1	37.25 j-n	33.36 j-n	63.21 e-i	51.40 f-j
5X1	47.53 de	42.56 de	66.33 d-g	56.97 c-f
6X1	50.24 cd	44.99 cd	67.62 def	57.35 c-f
7X1	34.09 m-p	30.52 m-p	65.85 d-g	55.45 d-h
8X1	40.53 f-k	36.29 f-k	65.00 d-i	56.50 d-g
9X1	38.68 i-m	34.63 i-m	63.01 e-i	52.47 e-j
10X1	33.52 nop	30.01 nop	75.22 ab	64.81 ab
1X2	60.00 a	53.75 a	80.09 a	68.05 a
2X2	39.99 f-l	35.84 f-l	68.67 b-e	59.96 bcd
3X2	46.73 de	41.85 de	69.85 b-e	57.22 c-f
4X2	38.88 h-m	34.81 h-m	68.16 c-f	55.16 d-h
5X2	51.58 cd	46.19 cd	69.74 b-e	60.05 bcd
6X2	54.74 bc	49.03 bc	70.89 bcd	60.20 bcd
7X2	37.03 j-n	33.17 j-n	68.89 b-e	57.26 c-f
8X2	43.75 e-h	39.18 e-h	70.63 bcd	61.03 bcd
9X2	41.41 f-j	37.11 f-j	65.55 d-h	55.03 d-i
10X2	36.82 j-n	32.97 j-n	78.51 a	67.96 a
1X3	50.46 cd	45.18 cd	69.51 b-e	57.12 c-f
2X3	36.35 k-o	32.54 k-o	58.87 h-k	49.66 hij
3X3	39.35 g-l	35.23 g-l	60.66 g-j	48.91 ijk
4X3	33.67 nop	30.15 nop	52.78 k	43.50 k
5X3	42.79 e-i	38.32 e-i	59.82 g-j	50.06 hij
6X3	44.74 ef	40.06 ef	61.71 f-j	50.85 g-j
7X3	31.51 op	28.21 op	58.66 ijk	48.94 ijk
8X3	35.87 k-o	32.12 k-o	59.96 g-j	50.74 g-j
9X3	35.27 l-p	31.58 l-p	55.13 jk	46.44 jk
10X3	30.34 p	27.16 p	69.21-e	59.24 cd

1. $LSD_{0.05}$. First year: G: 2.38 SD: 0.95 G X SD: 4.94. Second Year: G: 2.15 SD: 0.86, G X SD: 4.47
2. $LSD_{0.05}$: First Year: G: 3.32, SD: 1.33, G X SD: 6.88. Second Year: G: 2.95 SD: 1.18 G X SD: 6.12

Plant height at maturity (cm): The tallest plants were recorded for genotypes NIFA-Insaf and Local Bhakkar having 74.74 and 74.31 cm of plant height, respectively. Genotypes that fall into the category of medium tall having 66.74, 66.14, 65.50, 65.29 and 65.20 cm height were Shalkot, Pakistan-13, NARC-09, Shakar-2013 and Gandum-1, respectively. Tatara was the shortest genotype with minimum plant height of 61.23 cm. Effect of planting depth on plant height revealed that 10 cm depth resulted in tallest plants with 71.10 cm of plant height. Data collected in second year showed that genotypes like Local Bhakkar and NIFA-Insaf produced statistically similar and tallest plants with 64.00 and 62.75 cm of height, respectively. Results obtained during second year showed that planting seed at 10 cm of depth produced the tallest plants as found in first year. Interaction between the two factors i.e., genotypes and planting depths show that various genotypes showed different performance in term of plant height. The NIFA-Insaf showed tallest plant height at all sowing depths while Bhattor-2008 and Tatara showed poor performance with minimum plant height at all depths. The plant height was even shorter when both of these were planted at deepest depth i.e., 15 cm. It has been reported by several researcher in the past that most of the times genotypes maintain the character of height and each genotype possess specific plant height. Khokhar *et al*., (2010) has reported that variation in genotypes for plant height is certain. Similarly, studies carried out by Keshtkar *et al*., (2009) found that plants were taller when wheat was planted 10 cm depth. Strydhorst (2021) also reported that height of the wheat plants is correlated with coleoptile length and taller varieties having longer coleoptiles.

Number of fertile tillers: Number of fertile tillers determines the grain yield in wheat. Data presented in Table 3 showed that the highest number of fertile tillers were counted for NIFA-Insaf i.e. 13.20 (first year) and 11.88 tillers (second year). Three other genotypes Shalkot, shahkaar-13 and Pakistan-13 were found better as well. NARC-09 and Local Bhakkar were at bottom by producing least number of fertile tillers. Looking into results obtained for the effect of planting depths it was noted that seeding depth of 10 cm revealed the highest number of fertile tillers plant^{-1}.followed by 5 cm planting depth. Same findings were recorded during the both years of studies. Interaction between genotypes and sowing depths presented in Table 3 reveals that the genotype 'NIFA-Insaf' produced greater number of fertile tillers at planting depths being maximum at 10 cm of depth while the genotype 'Local Bhakkar' was found to be the poorest one and produced the least number of fertile tillers at sowing depths each year. Better moisture availability at normal sowing (10 cm deep) might have increased the number of fertile tillers in the current study. Rebetzke *et al*., (2007) stated that seed production was decreased at planting seed deeper than 10 cm and it was result of highest rate of reduced percent emergence. The current studies showed that sowing wheat seed at 10 cm depth showed maximum number of fertile tillers which may have been the results of better availability of moisture at this depth which has been depicted in (Fig. 1) where moisture level at 10 cm depth decreased gradually as compared with level at shallower depth. Although moisture level at 15 cm depth was better than level at 10 cm depth but emergence capability of plants was too less at 15 cm depth therefore it might have been the fact that fertile tillers at 15 cm were lower. This phenomenon has been explained by Rebetzke *et al*., (2007) as well.

Spike length: Spike length was found significantly different for various genotypes. NIFA-Insaf and NARC-09 produced the longest spikes having 10.02 cm and 9.03 cm in first year and 10.51 cm and 9.47 cm in second year, respectively (Table 3). Local Bhakkar was at the bottom with 7.05 cm and 66.35 cm long spikes during first and second year, respectively. It was further observed that optimum planting depth i.e. 10 cm resulted in maximum spike length while spike length decreased at shallower and deeper plantings during both years of study. Interaction study showed that maximum spike length (12.77 cm) was measured for NIFA-Insaf when it was planted at the 10 cm of depth while minimum length of spike (5.75 cm) was measured for Gandum-1 by planting it at 15 cm of depth. Alam *et al*., (2014) evaluated sever genotypes and reported that each genotype produced spikes of different length. Roy *et al*., (2011) has reported that length of the spike is reduced at deeper plantings. The current findings has been found in line with the findings of above mentioned researchers that spike length is not the same for all genotypes and size of spike can be shorter if wheat is planted deeper in the soil.

Number of grains (spike^{-1}): Total grains in a spike determine the total grain yield. The genotype NIFA-Insaf was the best among the group tested during this study and produced the highest number of grains spike^{-1} i.e. 50.24 (Table 4). The NIFA-Insaf was followed by Shahkar-2013 and Shalkot that produced 37.31 and 35.15 grains spike^{-1}. A genotype Local Bhakkar was at the bottom by producing least number of grains i.e., 22.62 spike^{-1}. Looking into the results obtained for effect of sowing depth it was observed that optimum sowing depth i.e. 10 cm resulted in maximum grains (39.84 spike^{-1}) whereas the deepest plants wheat (15 cm deep) showed least number with 24.91 grains spike^{-1}. Results obtained for interaction between the two factors are presented in Table 4 which showed that genotype 'NIFA-Insaf' produced maximum number of grains spike^{-1} both years at all sowing depths however the number was the highest at 10 cm depth. Local Bhakkar remained at the bottom with least grains spike^{-1} each year. Number grains were reduced at deepest showing each year. Kilic & Yağbasanlar (2010) stated that plants with high chlorophyll content produce maximum grains per spike which has been proved during the current study that genotypes having higher SPAD value had the spikes with maximum number of grains. It is proved that chlorophyll content in the leave is positively correlated with grains spike^{-1}. It has been further verified that planting seed at variable depths significantly affect grains spike^{-1} as reported by Roy *et al*., (2011).

Table 3. Number of fertile tillers (pot^{-1}) and spike length (cm) of various wheat genotypes as influenced by variable planting depth.

Genotypes (G)	Number of fertile tillers (pot^{-1})[1]		Spike length (cm)[2]	
	Year-1	Year-2	Year-1	Year-2
1. NIFA-Insaf	13.20 a	11.88 a	10.02 ab	9.03 ab
2. NARC-09	9.74 cd	8.77 cd	10.51 a	9.47 a
3. Pakistan-13	11.10 bc	10.00 bc	9.25 bc	8.33 bc
4. Bathoor-2008	10.24 bcd	9.22 bcd	8.75 c	7.89 c
5. Shahkar-2013	11.10 bc	10.00 bc	9.29 bc	8.37 bc
6. Shalkot	11.34 b	10.22 b	9.18 bc	8.27 bc
7. AARI-2008	10.11 bcd	9.11 bcd	8.25 cd	7.43 cd
8. Gandum-1	10.73 bc	9.66 bc	7.57 de	6.82 de
9. Tatara	10.11 bcd	9.11 bcd	7.30 de	6.57 de
10. Local Bhakkar	9.00 d	8.11 d	7.05 e	6.35 e
Sowing depth (SD)				
1. 5 cm	11.25 b	10.13 b	9.12 b	8.21 b
2. 10 cm	13.35 a	12.03 a	10.24 a	9.22 a
3. 15 cm	7.40 c	6.66 c	6.79 c	6.12 c
G X SD				
1X1	14.06 ab	12.66 ab	9.88 b-f	8.90 b-f
2X1	9.99 d-g	9.00 d-g	11.57 abc	10.42 abc
3X1	11.84 b-e	10.66 b-e	10.08 b-e	9.08 b-e
4X1	11.10 c-f	10.00 c-f	9.66 b-h	8.71 b-g
5X1	11.10 c-f	10.00 c-f	9.52 c-h	8.57 c-h
6X1	12.20 b-e	11.00 b-e	9.85 b-f	8.87 b-f
7X1	11.10 c-f	10.00 c-f	8.26 d-j	7.44 d-j
8X1	11.09 c-f	10.00 c-f	7.74 e-k	6.98 e-k
9X1	11.09 c-f	10.00 c-f	7.65 f-k	6.89 f-k
10X1	8.87 f-i	8.00 f-i	6.97 ijk	6.28 ijk
1X2	15.91 a	14.33 a	12.77 a	11.50 a
2X2	11.84 b-e	10.66 b-e	11.93 ab	10.74 ab
3X2	13.68 abc	12.33 abc	10.85 abc	9.78 abc
4X2	12.57 bcd	11.33 bcd	10.68 abc	9.62 abc
5X2	14.05 ab	12.66 ab	10.77 abc	9.70 abc
6X2	13.69 abc	12.33 abc	10.41 a-d	9.38 a-d
7X2	12.95 bc	11.66 bc	9.72 b-g	8.75 b-g
8X2	13.69 abc	12.33 abc	9.21 c-i	8.29 c-i
9X2	12.95 bc	11.66 bc	8.24 d-j	7.43 d-j
10X2	12.21 b-e	11.00 b-e	7.81 e-k	7.04 e-k
1X3	9.62 e-h	8.66 e-h	7.43 g-k	6.69 g-k
2X3	7.40 g-j	6.66 g-j	8.03 d-k	7.24 e-k
3X3	7.77 g-j	7.00 g-j	6.81 jk	6.14 jk
4X3	7.03 hij	6.33 hij	5.92 jk	5.33 jk
5X3	8.14 g-j	7.33 g-j	7.59 f-k	6.84 f-k
6X3	8.14 g-j	7.33 g-j	7.29 h-k	6.56 h-k
7X3	6.29 ij	5.66 ij	6.76 jk	6.09 jk
8X3	7.40 g-j	6.66 g-j	5.75 k	5.19 k
9X3	6.29 ij	5.66 ij	5.99 jk	5.40 jk
10X3	5.92 j	5.33 j	6.36 jk	5.74 jk

1. $LSD_{0.05}$. First year: G: 1.40, SD: 0.56 G X SD: 2.91. Second Year: G: 1.27 SD: 0.50, G X SD: 2.63
2. $LSD_{0.05}$: First Year: G: 1.15, SD: 0.46, G X SD: 2.39. Second Year: G: 1.03 SD: 0.41 G X SD: 2.14

Table 4. Number of grains and 1000-grain weight of various wheat genotypes as influenced by variable planting depth.

Genotypes (G)	Number of grains ($spike^{-1}$)[1]		1000-grain weight (g)[2]	
	Year-1	Year-2	Year-1	Year-2
1. NIFA-Insaf	50.24 a	45.11 a	42.32 a	38.24 a
2. NARC-09	31.76 cd	28.52 cd	37.33 c	33.73 c
3. Pakistan-13	31.65 cd	28.44 cd	37.47 c	33.86 c
4. Bathoor-2008	31.60 cd	28.40 cd	35.51 d	32.09 d
5. Shahkar-2013	37.31 b	33.50 b	39.15 b	35.38 b
6. Shalkot	35.15 bc	31.56 bc	39.59 b	35.78 b
7. AARI-2008	28.64 d	25.72 d	35.86 d	32.41 d
8. Gandum-1	28.23 d	25.36 d	38.74 b	35.01 b
9. Tatara	29.69 d	26.67 d	37.62 c	33.98 c
10. Local Bhakkar	22.62 e	20.32 e	35.03 d	31.65 d
Sowing depth (SD)				
1. 5 cm	33.32 b	29.92 b	38.25 b	34.57 b
2. 10 cm	39.84 a	35.77 a	40.00 a	36.15 a
3. 15 cm	24.91 c	22.38 c	35.33 c	31.92 c
G X SD				
1X1	50.17 b	45.05 b	44.21 a	39.95 a
2X1	31.80 f-j	28.54 f-l	38.50 d-g	34.79 d-g
3X1	31.38 f-j	28.20 f-l	37.13 g-j	33.55 g-j
4X1	32.09 f-j	28.84 f-l	35.19 i-m	31.81 i-m
5X1	38.92 c-f	34.94 c-f	39.33 d-g	35.54 d-g
6X1	35.97 d-h	32.29 d-h	39.37 d-g	35.57 d-g
7X1	29.65 g-k	26.62 g-m	36.12 h-k	32.64 h-k
8X1	28.84 g-k	25.91 g-m	39.54 c-f	35.73 c-f
9X1	31.52 f-j	28.33 f-l	38.52 d-g	34.79 d-g
10X1	22.84 kl	20.51 mn	34.65 klm	31.30 klm
1X2	63.82 a	57.29 a	44.16 a	39.90 a
2X2	38.14 c-f	34.26 c-f	38.52 d-g	34.80 d-g
3X2	40.66 cde	36.50 cde	40.07 b-e	36.22 b-e
4X2	36.97 c-g	33.21 d-g	38.19 e-h	34.51 e-h
5X2	45.23 bc	40.61 bc	42.10 ab	38.04 ab
6X2	42.72 bcd	38.34 bcd	41.68 bc	37.66 bc
7X2	33.57 e-j	30.15 e-k	38.53 d-g	34.81 d-g
8X2	34.36 e-i	30.85 e-j	40.51 bcd	36.61 bcd
9X2	35.05 d-i	31.50 d-i	38.91 d-g	35.15 d-g
10X2	27.89 h-k	25.04 h-m	37.39 f-i	33.78 f-i
1X3	36.73 d-g	32.98 d-g	38.60 d-g	34.88 d-g
2X3	25.35 jkl	22.77 lm	34.98 j-m	31.60 j-m
3X3	22.93 kl	20.62 mn	35.20 i-m	31.81 i-m
4X3	25.75 jk	23.15 klm	33.14 lm	29.95 lm
5X3	27.77 h-k	24.94 i-m	36.03 h-k	32.56 h-k
6X3	26.75 ijk	24.05 j-m	37.73 fgh	34.09 fgh
7X3	22.71 kl	20.40 mn	32.95 m	29.77 m
8X3	21.49 kl	19.32 mn	36.17 h-k	32.68 h-k
9X3	22.51 kl	20.20 mn	35.43 i-l	32.01 i-l
10X3	17.14 l	15.40 n	33.06 m	29.87 m

1. $LSD_{0.05}$. First year: G: 4.02 SD: 1.61 G X SD: 8.33. Second Year: G: 3.53 SD: 1.41, G X SD: 7.33
2. $LSD_{0.05}$: First Year: G: 1.11, SD: 0.44, G X SD: 2.30. Second Year: G: 1.00, SD: 0.40 G X SD: 2.07

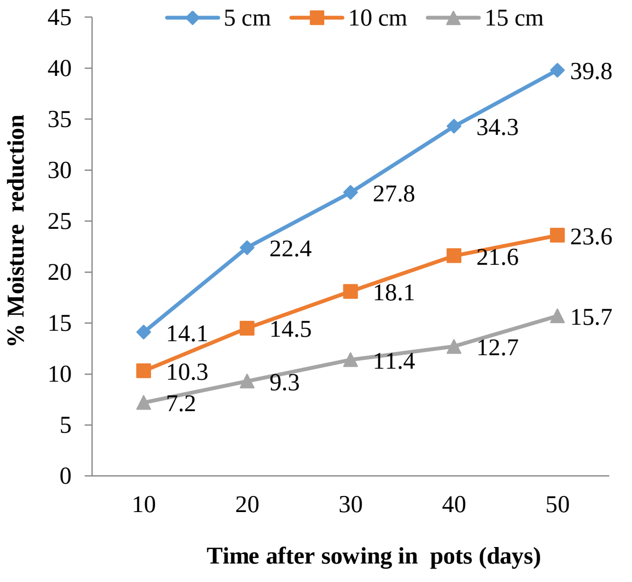

Fig. 1. Moisture reduction (%) at different depths of soil at 10 days time interval after sowing wheat in pots.

1000-grain weight (g): Significantly different weight of grains was observed for genotypes studied during the year 2016-2017 (Table 4). NIFA-Insaf was found to be the best having maximum 1000-grain weight of 42.32 g. Shalkot and Shahkar-2013 were better as well having 1000-grain weight of 39.59 g and 39.15 g, respectively during first year of study. Similar findings in second year were observed as NIFA-Insaf at the top followed by Shalkot and Shahkar-2013. Minimum 1000-grain weight of 35.86, 35.51 and 35.03 g was observed for genotypes AARI-2008, Bathoor-2008 and Local Bhakkar, respectively in first year. While Local Bhakkar was at bottom producing minimum 1000-grain weight of 31.65 g. Looking into the results obtained for effect of depth of planting it was found out that wheat sowing at 10 cm of depth resulted in heavier grains i.e., 40.00 g in first year and 36.15 g in second year of study. Minimum grain weight of 35.33 g was recorded for plants grown at 15 cm of depth in first year 31.92 g in second year. Results obtained for interaction between the two factors showed that the genotype 'NIFA-Insaf' always produced maximum 1000-grain weight both year and at each sowing depth however it was the highest at 10 cm of depth both years. Roy *et al*., (2011) reported that variable sowing depths could not produce significant effect on grain weight however they further reported that a trend was observed that deeper the sowing the lower the grain weight.

Grain yield (kg ha^{-1}): Grain yield was obtained significantly different for various genotypes (Table 5). NIFA-Insaf was found to be the best both years and produced the highest grain yield of 3014.80 ha^{-1} and 2195.50 kg ha^{-1} during first and second year, respectively. Minimum grain yield was obtained by Local Bhakkar each year with 772.00 kg ha^{-1} in first year and 563.30 kg ha^{-1} during second. Results obtained for effect of planting depths it has been noted that yield was significantly decreased when wheat was planted at 15 cm of depth by producing 678.00 kg ha^{-1} in first year and 494.60 kg ha^{-1} during the second year of study. The highest grain yield of 2201.80 kg was recorded at 10 cm depth during first year and 1607.70 kg ha^{-1} during the second year. Aikins *et al*., 2006, Mohan *et al*., 2013 and Farhad *et al*., (2014) have reported that variation for grain yield among genotypes exists in nature and grain yield potential is greatly reduced at deeper sowing.

Biological yield (kg ha^{-1}): As grain yield was recorded different for various genotypes tested the biological yield was found different as well (Table 5). NIFA-Insaf was found to be the best by producing the highest biological yield of 6423.50 kg ha^{-1} in first year and 4677.80 kg ha^{-1} during second year of study. Minimum biological yield of 1850.60 kg ha^{-1} and 1350.20 kg ha^{-1} was recorded for Local Bhakkar during first and second year, respectively. The data collected during first year of study further revealed that wheat planting at three different depths produced significantly different yield both years. The highest biological yield of 4597.30 kg ha^{-1} was obtained by planting the wheat at 10 cm depth during first year and 3357.00 kg ha^{-1} during the second year of study. As it was found for grain yield biological yield was also decreased at deeper sowing and minimum biological yield was recorded at the deepest sowing each year. Results obtained for first year showed minimum yield of 1687.40 kg ha^{-1} and in second year it was 1231 kg ha^{-1}. Studies carried out by several researcher Desbiolles (2002), Aikins *et al*., (2006) and Mohan *et al*., (2013) revealed that extremely deep sowing always results in reduced crop emergence, slow growth and decreased yields. Current findings suggest the similar recommendations as suggested by above mentioned researchers that sowing deeper than a particular depth results in decreased yields and poor crop establishment.

Correlation co-efficient: Correlation coefficient among the various yield contributing characteristics was calculated and presented in (Tables 6 and 7). Although a positive correlation was observed among parameters during both years of study however it was strongest between grains spike^{-1} and grain yield with r^2 values of 0.96 both years.

Determination of moisture content: Moisture content available at three different depths was determined throughout the season at various times. Figure-1 shows the percent moisture reduction at three different depths. It was observed that moisture content decreased with increase in time period. Since differences among genotypes planted at three different depths for all measured parameters were found statistically significant and it is believed that all these differences are the result of moisture content available at three depths. Decline in moisture content was rapid at shallower depth as compared to deeper levels. The last observation was recorded 50 days after sowing which showed 39.8% decrease in moisture at 5 cm depth and 23.6% at 10 cm depth. Minimum reduction (15.7%) was recorded at 15 cm depth on day 50.

Table 5. Number of fertile tillers (pot^{-1}) and spike length (cm) of various wheat genotypes as influenced by variable planting depth.

Genotypes (G)	Grain yield ($kg\ ha^{-1}$)[1]		Biological yield ($kg\ ha^{-1}$)[2]	
	Year-1	Year-2	Year-1	Year-2
1. NIFA-Insaf	3014.80 a	2195.50 a	6423.50 a	4677.80 a
2. NARC-09	1211.60 c	883.00 c	2714.30 c	1978.20 c
3. Pakistan-13	1406.60 bc	1028.00 bc	3113.60 bc	2275.40 bc
4. Bathoor-2008	1208.40 c	884.40 c	2821.50 c	2064.90 c
5. Shahkar-2013	1732.00 b	1264.70 b	3738.60 b	2729.80 b
6. Shalkot	1666.50 b	1216.70 b	3614.00 b	2638.60 b
7. AARI-2008	1115.40 cd	813.70 c	2652.60 c	1935.10 c
8. Gandum-1	1250.00 c	913.30 c	2652.60 c	1970.20 c
9. Tatara	1205.00 c	881.70 c	2759.50 c	2018.90 c
10. Local Bhakkar	772.00 d	563.30 d	1850.60 d	1350.20 d
Sowing depth (SD)				
1. 5 cm	1495.00 b	1091.00 b	3430.60 b	2503.70 b
2. 10 cm	2201.80 a	1607.70 a	4597.30 a	3357.00 a
3. 15 cm	678.00 c	494.60 c	1687.40 c	1231.00 c
G X SD				
1X1	3147.00 b	2291.70 b	6923.50 b	5041.70 b
2X1	1234.30 f-j	898.90 f-k	2838.90 f-k	2067.40 f-j
3X1	1373.10 fg	1002.40 fgh	3213.00 e-h	2345.50 e-h
4X1	1251.50 f-i	915.90 f-k	3003.60 e-i	2198.20 f-i
5X1	1699.20 ef	1239.50 efg	3772.30 def	2751.70 def
6X1	1735.20 def	1266.30 efg	3886.80 def	2836.60 def
7X1	1194.20 f-k	870.70 g-l	2925.80 f-j	2133.20 f-i
8X1	1268.70 f-i	927.90 f-j	2841.80 f-k	2078.40 f-j
9X1	1344.50 fgh	984.90 f-i	3159.60 e-h	2314.60 e-h
10X1	701.90 g-l	511.90 h-m	1740.80 g-l	1269.60 h-k
1X2	4516.20 a	3290.40 a	9032.30 a	6580.70 a
2X2	1742.80 def	1270.20 efg	3659.80 def	2667.50 def
3X2	2225.30 cde	1627.60 cde	4561.80 cde	3336.50 cde
4X2	1777.00 def	1302.20 d-g	3909.40 cdef	2864.70 def
5X2	2681.50 bc	1959.80 bc	5470.30 bc	3998.10 bc
6X2	2444.00 bcd	1783.40 cd	4961.20 cd	3620.30 cd
7X2	1677.00 ef	1224.40 efg	3773.20 def	2755.00 def
8X2	1908.70 def	1393.40 def	3855.50 def	2814.80 def
9X2	1766.30 def	1292.90 d-g	3832.90 def	2805.50 def
10X2	1279.10 f-i	932.90 f-j	2916.30 f-j	2127.00 f-i
1X3	1381.10 fg	1004.60 fgh	3314.60 efg	2411.00 efg
2X3	657.70 g-l	479.90 i-m	1644.20 h-l	1199.70 ijk
3X3	621.40 h-l	454.10 j-m	1566.00 i-l	1144.20 ijk
4X3	596.70 i-l	435.30 j-m	1551.40 i-l	1131.70 ijk
5X3	815.40 g-l	594.80 h-m	1973.20 g-l	1439.50 g-k
6X3	820.50 g-l	600.40 h-m	1993.80 g-l	1459.00 g-k
7X3	475.00 kl	346.10 m	1258.80 l	917.10 k
8X3	572.70 i-l	418.70 klm	1391.70 jkl	1017.40 jk
9X3	504.20 jkl	367.30 lm	1285.80 kl	936.60 k
10X3	335.10 l	245.00 m	894.80 l	654.20 k

1. LSD0.05- 1st year: G: 357.89 SD: 143.39 G X SD: 741.82. 2nd Year: G: 243.96 SD: 97.74, G X SD:505.86
2. $LSD_{0.05:}$ 1st Year: G: 760.72, SD: 304.78, G X SD: 1576.8. 2nd Year: G: 523.83 SD: 209.87 G X SD: 1085.8

Table 6. Correlation among wheat grain yield and yield contributing parameters during the year-1.

	Spike length (cm)	Number of grains (spike^{-1})	Number of fertile tillers (pot^{-1})	1000-grain weight (g)
Number of grains (spike^{-1})	0.77**	---	---	---
Number of fertile tillers (pot^{-1})	0.73**	0.80**	---	---
1000-grain weight (g)	0.65**	0.80**	0.81**	---
Grain yield (kg ha^{-1})	0.74**	0.96**	0.87**	0.87**

Table 7. Correlation among wheat yield and yield contributing parameters during the year-2.

	Spike length (cm)	Number of grains (spike^{-1})	Number of fertile tillers (pot^{-1})	1000-grain weight (g)
Number of grains (spike^{-1})	0.77**	---	---	---
Number of fertile tillers (pot^{-1})	0.73**	0.80**	---	---
1000-grain weight (g)	0.66**	0.85**	0.80**	---
Grain yield (kg ha^{-1})	0.74**	0.96**	0.87**	0.87**

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