

*Full Length Research Paper*

# Growth and yield parameters as potential indicators of selection for moisture deficit tolerance in some Pakistani wheat (*Triticum aestivum* L.) cultivars

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The present study evaluated growth, yield and yield components of three wheat cultivars (Bhakher-2002, Inqalab-91 and Punjnad-2001) under varying degree of soil moisture deficit. The cultivars were grown under 60 and 20% soil moisture along with their control. Intensive moisture deficit induced more drastic ( $P < 0.001$ ) effect on the performance of the cultivar as compared with moderate moisture deficit regime. Among the tested cultivar, Bhakher-2002 had better root and shoot growth under both moisture deficit situations. However, Punjnad-2001 excelled for germination, spike length, number of grains per spike and grain weight under moisture deficit environment. On the other hand, both growth and yield attributes appeared to be more prone in Inqalab-91 under moisture deficit conditions. The sensitivity of Bhakher-2002 and inqalab-91 can be attributable to insufficient gene pool of the cultivars which could not ensure their continued evolution and adaptation under prevalent stress conditions. Therefore, these two cultivars have not shown a threshold for moisture deficit. Conversely, the moisture stress tolerance in Punjnad-2001 may be manifestation of the occurrence of appropriate genetic variability for yield attributes within its existing gene pool which enabled the cultivar to evolve under strong selective pressures of increasing soil moisture deficit. Therefore, Punjnad-2001 can be recommended for molecular characterization to identify marker for drought tolerance.

**Key words:** Wheat germplasm, selective pressure, soil moisture deficit, growth and yield.

## INTRODUCTION

Several environmental stresses affect growth and development of crop species by influencing developmental, structural, physiological, biochemical processes thus causing overall reduction in yield (Gaspar et al., 2004). Being an arid country, Pakistan already experiences sub-optimal growth conditions for agriculture. Among various environmental stresses, drought or availability of low soil moisture is particularly of great concern because continental type of climate characterizes the country, which is predominantly arid. Moreover, there is an extreme spatial and temporal variability of temperature, which causes changes in soil moisture. In addition, low rainfall and unavailability of

sufficient water for irrigation besides topographical factors result in variable soil moisture (Shakhatreh et al., 2001; Wani et al., 2009). All these factors seem to pose limitations for crop agriculture. A vast area (56592 km<sup>2</sup>) under four deserts (Thal, Thar, Cholistan and Kharan), evidently illustrate overall situation of the country where low rain fall and rapidly percolating water owing to sandy soils, are major causes of considerable moisture deficit situations for crop production (Ashraf, 2006).

The moisture deficit conditions are responsible for greater losses to agricultural productivity throughout the world (Reynolds et al., 2007). Thus, unavailability of sufficient moisture can substantially impede crop productivity and is regarded as the second largest contributor to yield reduction after diseases in some areas of the world; economic losses due to an extended scarcity of water may account billions of dollars (Ciais,

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2005).

Wheat (*Triticum aestivum* L.) is a staple food and a principal cereal crop of world including Pakistan. The rapidly growing population of the country has to rely on wheat for its food requirements. Consequently, a large area (9.046 million hectares) with an average yields of 2.66 tones/ha with a total production of 24.033 million tones is used for its cultivation during 2008-09 (Anonymous, 2010). Though, Pakistan ranks at 10<sup>th</sup> position in wheat production but water deficit conditions mainly accounts low production of this crop (FAOSTAT, 2008). Nevertheless, in order to meet the food demand of the population the most plausible approach is to identify and grow those wheat cultivars that have the maximum yield potential under water deficit situations.

Availability of appropriate soil moisture is the prime requisite for crop growth and development. However, optimum water requirement varies considerably both at inter and intra-specific levels. Therefore, exploitation of crop cultivars which have better potential to cope with varying soil moisture would be imperative in assessing overall success of a crop under moisture deficit environment (Garcia et al., 2003). Moisture deficit conditions induce changes at physiological, biochemical and molecular levels (Akram et al., 2010). However, the ability of crop species/ cultivars for stress tolerance mainly depends on the existence of appropriate variability within their gene pool. Therefore, performance of genotypes for growth and yield parameters has widely been evaluated after applying strong selection pressures (Trethowan and Kazi, 2008). Thus, the ability of the germplasm to evolve for a particular set of environmental stress can provide basis of selection criteria (Yousaf et al., 2008). Therefore, the present study aimed to assess the variability of several growths and yield attributes of commonly cultivated wheat cultivars of the country under different moisture deficit regimes. The foremost objective of the study was to reveal growth and agronomic traits that could serve as potential indicators for selection for moisture deficit tolerance as well as to provide tools for the identification of molecular markers in wheat germplasm.

## MATERIALS AND METHODS

### Germination experiment

Seeds of three wheat cultivars (Bhakher-2002, Inqalab-91 and Punjnad-2001) were obtained from Seed Corporation Punjab, Pakistan. The germination experiment was conducted in the laboratory at temperature 25 ±5°C, day light (13 h) and relative humidity 45%. Forty five Petri dishes (9 cm internal diameter) were washed with distilled deionized water and then oven dried. The Petri dishes were labelled appropriately for cultivars and moisture levels. Each Petri dish was filled with 60 g of soil (garden compost). The field capacity was estimated based on the water holding capacity of the soil and moisture deficit levels were comprised of field capacity of soil (FC). The treatments were 100 (Control), 60 and 20% soil moisture. There were made three replicates for each

treatment. The experiment was arranged in a complete randomized manner. Thirty seeds of each cultivar were sown into each of these Petri dishes. The seeds were observed for germination each day. When both embryonic root (radicle) and shoot (plumule) were emerged (0.2 cm) the seeds were considered germinated. The experiment was continued for 10 days until no further germination and then data records were made for germination percentage, radicle and plumule lengths.

### Growth experiment

The growth experiment was conducted in a wire netting green house at the Botanic Garden, Bahauddin Zakaryia University Multan, in Pakistan. The average day and night temperature were 25±4 and 20±3°C, respectively, the day length was 12 h and relative humidity was 55%. Twenty seven earthen pots (20 cm internal diameter and 15 cm height) were labelled for cultivars and moisture levels. Each pot was filled with 3 kg of soil (garden compost). The experiment was laid down in complete randomized manner. There were three replicates for each cultivars and moisture levels. Six pre-germinated seeds of cultivar were sown at equidistance into each pot which was then tinned out to three. Plants were allowed to establish for eight weeks then the following moisture deficit treatments were applied as follows:

T1= 100% soil moisture (irrigated based on F.C of soil).

T2= 60% soil moisture (irrigated based on F.C of soil).

T3= 20% soil moisture (irrigated based on F.C of soil).

Moisture levels were maintained by weighing each pot daily and water loss was compensated by applying water gently using a spray gun. Plants were exposed to moisture deficit treatments for 12 weeks. Various growth and yield attributes were recorded by consistent measurements for plant height, ear length and fresh weight of plant parts. Dry weight of plant material taken after oven drying plant at 70°C for 72 h.

### Statistical analysis

Data presented as mean values along with ±S.E for each parameter. Data for germination percentage was arcsine transformed following Bliss (1937) before it was subjected to statistical analysis. A two-way analysis of variance (ANOVA) was performed using MS-Excel 2004 in order to evaluate main effects of moisture deficit levels on various growth attributes as well as to reveal intraspecific variability.

Least significant differences (LSD) between means for cultivars and moisture levels were calculated following Duncan (1955) at 5% level of significance to elucidate real differences between moisture levels and cultivars.

## RESULTS AND DISCUSSION

The data for germination experiment clearly indicated different responses of the cultivars (Table 1). The results indicated that the highest level of soil moisture deficit had significantly ( $P < 0.01$ ) influenced seed germination, radicle and plumule length. The germination was consistently higher (100%) for all wheat cultivars at the maximum moisture level (Figure 1A). While, it declined up to 50% in Punjnad-2001 at the lowest (20%) moisture level as compared to its control. However, the extent of

**Table 1.** Summary of analysis of variance (Mean squares and significance) for various attributes in relation to increasing soil moisture deficit levels in some Pakistani wheat (*Triticum aestivum* L.) cultivars.

Attribute	MS varieties	Significance	MS moisture levels	Significance	MS interaction	Significance
<b>Germination</b>						
Germination percentage	253.52	**	10554.20	***	74.03	NS
Radicle length (cm)	1.87	**	39.82	***	0.11	NS
Plumule length (cm)	2.24	**	68.18	***	0.14	NS
<b>Growth</b>						
Fresh weight of root (g)	0.38	***	1.20	***	0.001	NS
Dry weight of root(g)	0.11	*	0.36	***	0.01	NS
Fresh weight of shoot (g)	1.58	***	3.24	***	0.05	NS
Dry weight of shoot (g)	1.55	***	5.22	***	0.03	***
Plant height (cm)	161.77	***	421.33	***	3.11	NS
<b>Agronomic/ yield</b>						
Spike length (cm)	3.38	***	13.88	***	1.28	**
Number of grains per spike	14.20	***	6.50	***	0.07	**
Grain weight (g)	1.53	**	15.03	***	0.60	***

MS = Mean square, NS = non-significant, \*, \*\*, \*\*\* = significant at P = 0.05, 0.01 and 0.001, respectively (df, cultivars = 2, levels = 2, interaction = 4, residual = 18).

decline was about 25% in Bhakher-2002 at the lowest moisture regime. The other moisture level did not adversely affect germination of all three cultivars.

An increase in soil moisture deficit retarded the elongation of both radicle and plumule. The lowest moisture level induced a considerable decline in radicle length as it decreased up to 29.35%, 25.13%, and 20.34% in Bhakher-2002, Inqalab-91, and Punjnad-2001, respectively (Figure 1B). All moisture deficit levels also caused a suppression of plumule elongation. The reduction was more drastic at the highest moisture deficit where the cultivar Bhakher-2002 had shown a reduction of 50.26% as compared to its control (Figure 1C). Among the cultivars, Punjnad-2001 had the lowest (35.17%) reduction than Inqalab-

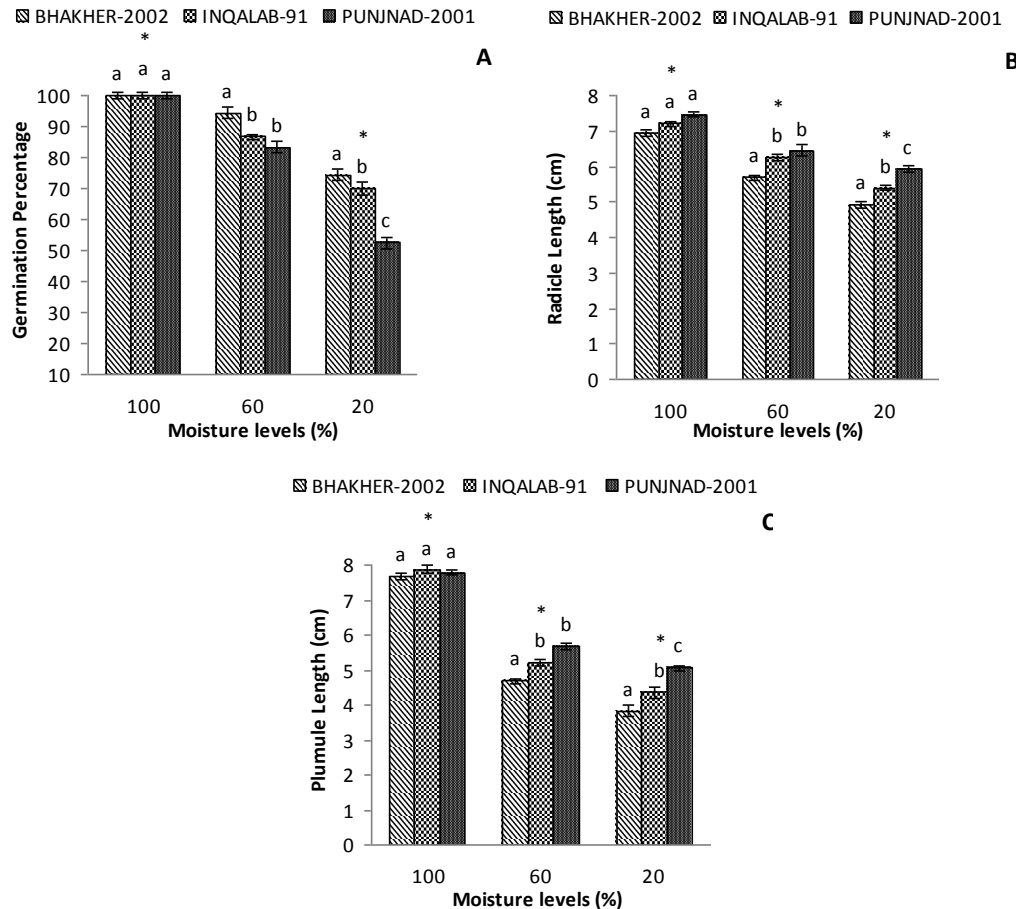
91 which showed 44.59% decline in plumule length at the 20% moisture level.

Germination is a crucial stage for the establishment of crop. It initiates as soon as water becomes available to seeds for imbibition. It is evident that moisture deficit of the soil hampered cell division and elongation which causes a decline in germination as well as elongation of embryonic axes (radicle and plumule). Several other studies (Rinaldi et al., 2005; Kaya et al., 2006) had clearly demonstrated suppression of cell expansion is a primary response to water deficit situations that results in reduced cell division and elongation. Thus, germination appeared to be the most sensitive stage to water deficit. Retardation of cell division and growth of plant tissues had also been reported by Ozturk

and Aydin (2004) under moisture deficit conditions.

The result of the study indicated that moisture levels up to 60% did not induce a profound decline but 20% moisture level had caused inhibition of germination process ( $P < 0.001$ ). The suppression of elongation of plumule was much drastic as compared to radicle growth. The cultivar Punjnad-2001 had shown its potential to cope with the highest level (20%) of moisture deficit. Thus, developmental ability of this cultivar at germination stage may signify its potential to grow under moisture deficit conditions. Such genotypic variability has also been reported in other wheat cultivars (Jajarmi, 2009; Rauf and Munir, 2010).

Table 1 clearly depicted that increasing moisture



**Figure 1.** Effect of increasing moisture deficit levels on (A), germination percentage (B), radicle length and (C) plumule length in some Pakistani wheat (*Triticum aestivum* L.) cultivars. Vertical lines represent  $\pm$ S.E, a-c and \* are significant difference between cultivars and moisture levels, respectively by Duncan's multiple range test at 5% level of probability.

deficit levels considerably ( $P < 0.001$ ) influence the production of biomass of above and below ground tissues. It is also evident that the cultivars had significantly ( $P < 0.001$ ) variable responses to various moisture deficit levels (Table 1).

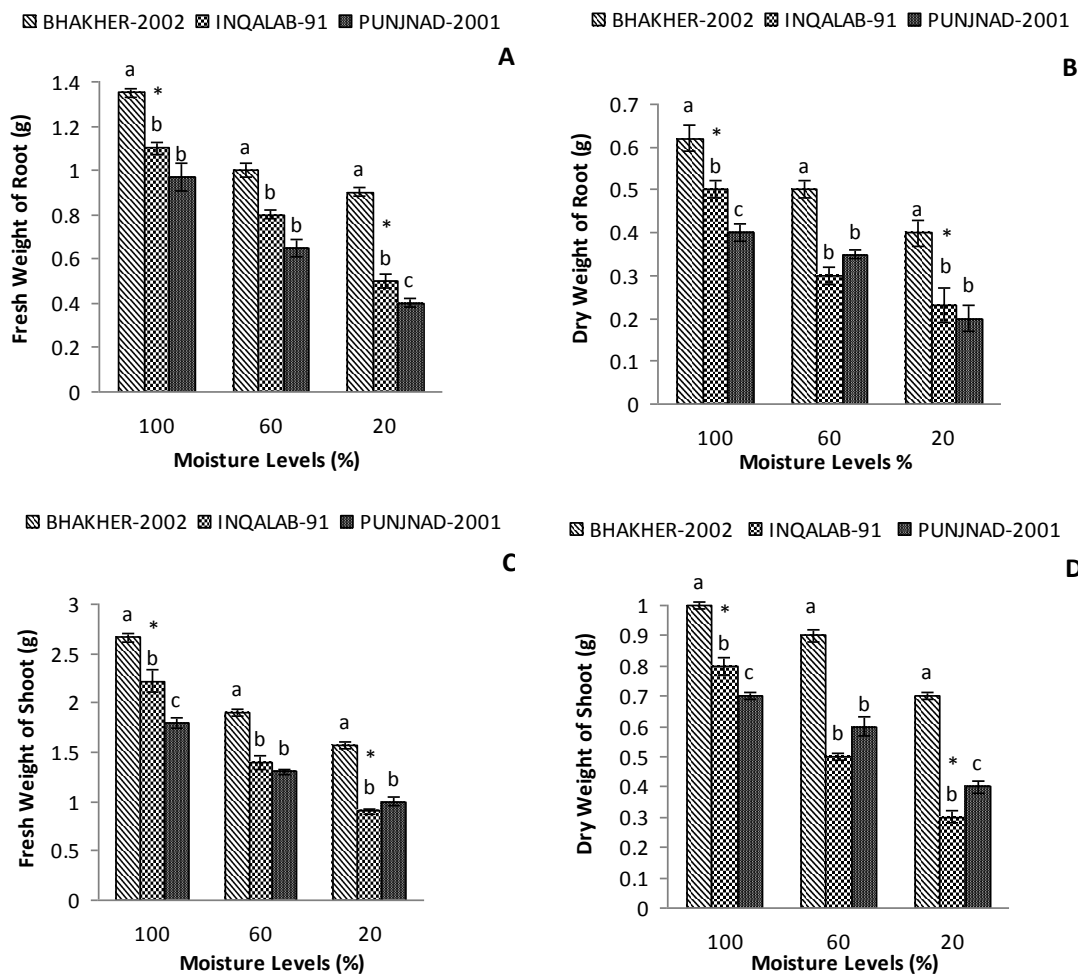
The lower level of soil moisture deficit did not cause any drastic decline in biomass production of the tissues. It is evident from (Figure 2) that Bhakher-2002 had consistently greater biomass of root and shoot at both moisture deficit levels. At the highest moisture deficit, Punjnad-2001 had shown 58 and 44% reduction in fresh biomass of root and shoot, respectively. However, fresh biomass of root declined up to 33% in Bhakher-2002 (Figure 2A). The maximum reduction of shoot (up to 55%) for fresh biomass (Figure 2C) was observed for Inqalab-91 at the 20% moisture level as compared to the control.

Trends of the cultivars for dry biomass of tissues were comparable to fresh biomass. The responses of the cultivars were consistent but among the tested cultivars Bhakher-2002 excelled for dry biomass of both root and

shoot (Figures 2B and D). With regard to plant height, the cultivars had the highest plant length at the maximum soil moisture level but a pronounced decline was observed at the highest moisture deficit level in all cultivars (Figure 2E). The reduction in plant height was the maximum (49%) in Bhakher-2002 followed by Inqalab-91 and Punjnad-2001 which showed 48 and 32% decline at 20% soil moisture.

Impact of different abiotic stresses including moisture deficit is frequently perceived through dry weight production. Since, desiccation tolerance is accomplished by different metabolic activities that include the synthesis of osmotically active substances, specific proteins and by-products (Dencic et al, 2000). Therefore, dry biomass can serve as one of the realistic predictors as it may signify cumulative effects of various adjustments in relation to moisture stress (Guttieri et al., 2001).

The results for biomass production and plant height clearly signified that moisture deficit conditions had differentially affected various growth attributes in the tested cultivars. An intermediate moisture deficit induced



**Figure 2.** Effect of increasing moisture deficit levels on (A), fresh weight of root (B), dry weight of root (C), fresh weight of shoot (D), dry weight of shoot and (E) plant height in some Pakistani wheat (*Triticum aestivum* L.) cultivars. Vertical lines represent  $\pm$  S.E. a-c and \* are significant difference between cultivars and moisture levels, respectively by Duncan's multiple range test at 5% level of probability.

a moderate decline; however, an intensive soil moisture deficit caused severe reduction of these growth parameters. These findings are in lines of many other workers (Saleem, 2003; Golabadi et al., 2006) who also identified intra specific variability for these traits.

Differential performance of the wheat cultivars for dry biomass clearly indicated the genotypic variability. Therefore, greater dry biomass of plants can be a manifestation of those mechanisms which involved in accumulation of such substances that have their role for moisture stress tolerance.

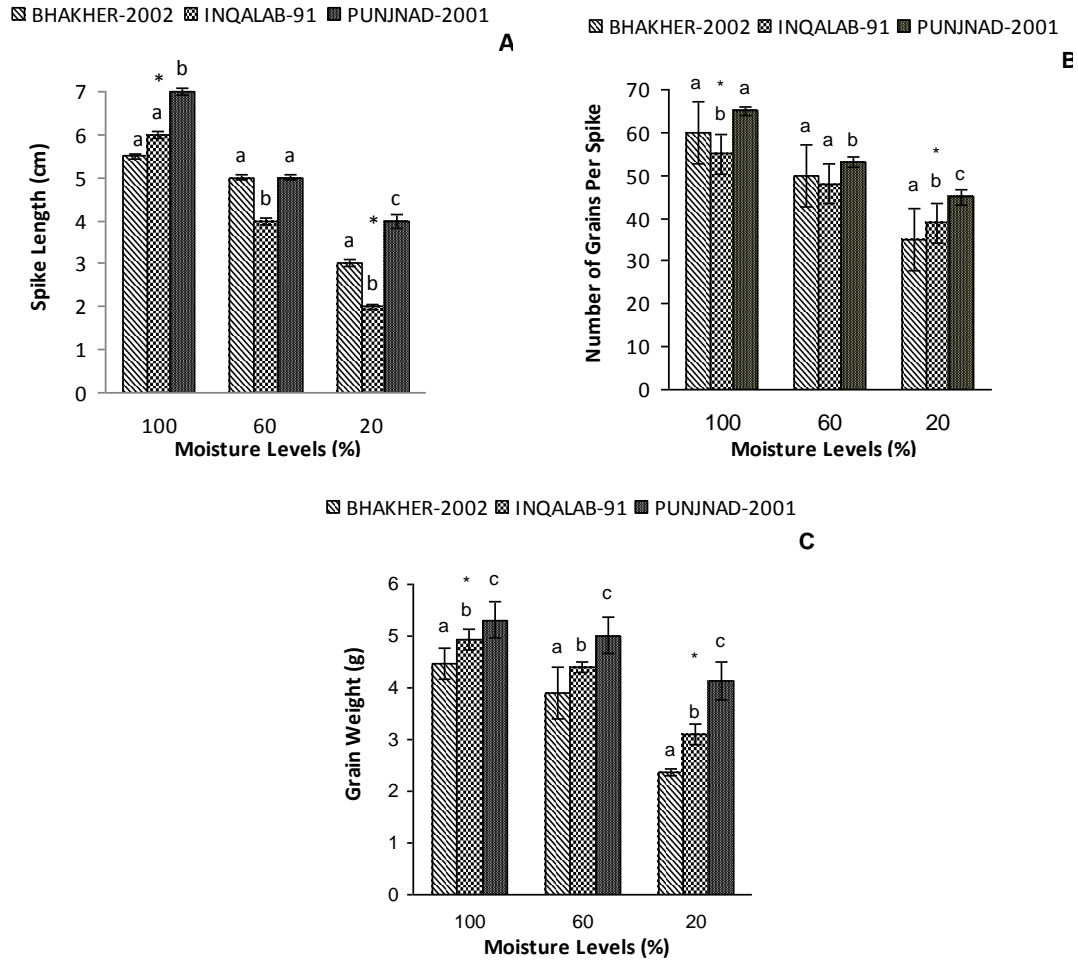
While considering the responses of the cultivars for different agronomic and yield attributes it became evident that soil moisture deficit conditions significantly ( $P < 0.001$ ) affected these attributes (Table 1). Statistical analysis also revealed a highly significant ( $P < 0.001$  for all traits and  $P < 0.01$  for grain weight) variability among cultivars (Table 1).

Spike length is an important parameter of wheat crop as grain/seed number, which is considered as the

foremost yield trait depends on this attribute. Generally, there is an affirmative relationship between spike length and number of grains. Therefore, several studies have considered this attribute in relation to water deficit conditions in wheat (Khan et al., 2010; Shabbir et al., 2011).

All cultivars produced longer spike when grown at the maximum moisture level. However, a gradual decline in spike length was noticed with increasing soil moisture deficit (Figure 3A). Inqalab-91 showed 33% reduction in spike length at 60% soil moisture when compared with its control.

Similarly, the reduction for spike length was about two folds (66%) at the lowest moisture level. Bhakher-2002 and Punjnad-2001 also showed less elongated spikes and the extent of reduction was 9 and 28% at 60% moisture level, respectively. However, the degree of decline was five times (40%) greater in Bhakher-2002 at the highest moisture deficit as compared with 60% soil moisture. The number of grain developed per spike can



**Figure 3.** Effect of increasing moisture deficit levels on (A), spike length (B), number of grains per spike and (C) grain weight in some Pakistani wheat (*Triticum aestivum* L.) cultivars. Vertical lines represent  $\pm$ S.E, a-c and \* are significant difference between cultivars and moisture levels, respectively by Duncan's multiple range test at 5% level of probability.

influence yield. Though, grain number per spike in wheat is genetically controlled but is greatly influenced by various environmental factors (Sanjeri et al., 2006).

The data suggested that moisture deficit differentially affected grain number in the tested wheat cultivars primarily by reducing an important yield component (Figure 3B). The effects of moisture deficit on yield component (grain number/ spike) were also evident (Table 1). The results suggested that grain number per spike was not much influenced by an intermediate moisture deficit conditions but severe moisture deficit induced 42% suppression in grain number in Bhakher-2002 while in Punjnad-2001 it was reduced upto 31% at the highest moisture deficit level. These findings are in lines of many other workers (Dogan, 2009; Vaezi et al., 2010). Who identified that the number of grains per spike had the most significant effect on yield.

Adverse effects of moisture deficit on grain yield became more evident through decline in the grain weight.

Though, grain weight was not much reduced by the moderate moisture deficit. However, the highest moisture deficit condition induced a significant ( $P < 0.01$ ) decline in grain weight (Figure 3C). Analysis of variance (Table 1) discriminated cultivars' responses to different moisture deficit conditions for grain weight. Bhakher-2002 appeared to be significantly susceptible to the highest moisture deficit situation as it had 47% decline compared with its control. The sensitivity of the other two cultivars was not much profound at 20% moisture level and exhibited 37 and 18.8% reduction, respectively. Again, an intermediate moisture deficit treatment had less adverse effect on grain weight whereas; severe moisture deficit had caused the most significant effect on yield. Similar results were also obtained by (Anwar et al., 2011; Abinasa et al., 2011) in a study when wheat cultivars were subjected to two moisture deficit regimes. Though, Bhakher-2002 was primarily developed for those areas of the country which have less rainfall, but its sensitivity in a

stress prone environment might be due to gradual loss of genetic variability within the primary gene pool of the cultivar and such findings have widely been reported for wheat (Trethowan and Kazi, 2008).

## Conclusion

The results of the study clearly suggested distinct responses for various growth and agronomic traits under moisture deficit environment. It is also obvious that intensive decline in moisture level had induced more drastic effects on the performance of the cultivars. However, less severity of moisture did not affect growth of the tested cultivars. While summing up the results, it can be concluded that the cultivar Punjnad-2001 performed better for 6 out of 11 attributes followed by Bhakher-2002 which excelled for 5 parameters. Bhakher-2002 had greater germination and biomass for root and shoot which is an indicative of the ability of growth under moisture deficit regimes but it showed sensitivity to moisture stress for yield attributes. On the other hand, Punjnad-2001 had consistently a better response for yield parameters. While, Inqalab-91 had shown an incoherent variability for the attributes studied.

Several traits which signify stress tolerance are quantitatively inherited. Therefore, genetic diversity for stress tolerance is necessary to be maintained. There seems to exist insufficient genetic variation in Bhakher-2002 and Inqalab-91 regarding their gene pools which could ensure their continued evolution and adaptation to an environmental stress. Punjnad-2001 seems to possess appropriate genetic variability and is able to evolve under strong selective pressures of moisture deficits. Moreover, genetic progress has been possible because of additive genetic variance particularly for yield within its existing gene pool under low soil moisture. Therefore, it can be recommended for molecular characterization to identify markers for drought tolerance.

Although, the genetic control of tolerance is complex and is poorly understood nevertheless, continuous improvement in wheat germplasm for stress prone environment is essentially required which should be based on empirical selection in the target environment.

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