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GENOTYPIC DIVERSITY OF PERENNIAL AND ANNUAL WHEAT FOR ROOT AND SHOOT BEHAVIOUR

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ABSTRACT

The agronomic and root growth performance of three perennial wheat varieties i.e CS + 4J (21 + 1), {(CIMMYT 4J Addition (21 + 1)} and (CS/Th. bessarabicum (complete amphiploid) 21+7) and three annual, including Inqulaib-91, B. Yellow and Claire were compared in Randomised Complete Block Design. The results revealed that root elongation of both groups ceased after 7th week. The tested genotypes maintained quantitative proportionality with respect to root and shoot development. Inter varietals within both groups could not produced statistically different values for plant height. The varieties lies in perennial group gave significantly encouraging results except plant height and dry weight over annuals for above as well as below ground plant parts but we can expect the limited grains production from perennials. Among annuals, the V3 and from perennial no single variety proved to be superior for all desirable traits. Both the groups distributed most of their root mass in upper 30 cm soil layer and only a minor portion of roots was extended to 120 cm depth. Even though, the varieties from perennial group performed well for plant biomass but it is never recommended to replace annuals with perennials for grains. However, their use as forage, soil and environment conservation crop is more reliable.

Key words: perennial wheat, genotypes, root architecture, seedling traits.

INTRODUCTION

The continuous cultivation of land for food and feed production from annual crops has threatened the soil capability to provide nutrients and water, and also the biodiversity of ecosystem. As a consequence of these long term drawbacks, the crops with perennial growth are gaining much attention in the world's agro systems (Cox et al., 2006). The perennial genotypes could keep the land intact with roots for carbon sequestration and reducing erosion for sustainable land use, with the ultimate objective of keeping pace with ever increasing global food demand. Taking the advantage of modern technologies of crop improvement, the breeders are now in a position to combine perennity with traits that directly add to final harvest.

Roots are very important part of plant, considering their function in nutrient and water uptake (Fitter et al., 1991) and transport to above tissues, but experimentation in field is limited, being labour intensive, time consuming and high cost (Zuo et al., 2004; Tsutsumi et al., 2003; Sarker et al., 2005). The great variation among varieties root traits resulting from genotypic diversity has been demonstrated in many crop species (O'Toole and Bland, 1987; Gregory et al., 2005; Ford et al., 2006). Furthermore, the distribution of vertical and horizontal root mass in different soil horizons is controlled by genotypic diversity and soil characters (Ridge, 1991).

There is strong coordination among plant parts activity and for obtaining higher yield, there must be compromise for leaf canopy and root systems for intercepting solar radiation and mineral and water uptake, respectively. Now, it has been recognized that the sense of roots for changes occurred in soil are immediately transferred to above ground plant parts. One of such example is synthesis of ABA hormone in roots and its urgent delivery

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to leaves for the purpose of stomatal closure in case of moisture deficient soil (McDonald and Davies, 1996).

The variation in root behaviour also induces changes in aboveground morphological traits and often restricts the canopy growth in poor soil root system management.

The equilibrium or relative proportion of root and shoot should be maintained. As cereals are the main staple food of the world, a better knowledge of their root growth and relative distribution in soil depth can be helpful for designing efficient irrigation and nutrient management programme for the growing season. The root-shoot ratio studies are important in order to estimate the carbon addition in soil at harvest.

These studies have shown that the shoot-root ratio directly depends upon on root mass, and in general on cultivation practices (Bolinder et al., 1999).

It is also evident that variability of varieties for their response to soil condition and their potential should be explored for recommending varieties in accord with soil conditions.

MATERIAL AND METHODS

A pot experiment was conducted at Henfaes Research Centre, University of Wales, Bangor, during the year 2005 in glass house without temperature regulating system. The rhizotron (2 cm deep × 30 cm wide ×120 cm height) was filled with 50:50 top soil and sand. The top soil used has a Ph of 7.20, P contents 25 ppm, K contents 126 ppm, N content 0.15% and organic matter content of 8.21%.

Three seeds were sown in each rhizotron on 21 October and were thinned to one healthy seedling at three leaf stage. The rhizotron were watered at 4 days intervals upto field capacity level. The three perennial and annual wheat varieties were compared in Randomised Complete Block Design (RCBD). The detailed information of varieties is as follows:

Variety name	Origin	Growth habit	Abbre-viation
CS + 4J (21 + 1)	USA	Perennial	V1
CIMMYT 4J Addition (21 + 1)	USA	Perennial	V2
[CS/*Th. bessarabicum* (complete amphiploid) 21+7]	USA	Perennial	V3
Inquilab-91	Pakistan	Annual	V1
B. Yellow	India	Annual	V2
Claire	UK	Annual	V3

The treatments were repeated three times. The rhizotron was fertilized with phostrogen (N, P_2O_5 and K_2O 14:10:27%) at rate of 100 kg ha^{-1}. Half of the fertilizer was used with sowing and the remaining was applied at 25 days after sowing. The rhizotron were kept weed free through growing season by hand pulling. New roots visible on the glass were traced on a transpar ent acetate sheet using different colours for each recording occasion. The root length was measured by means of an opisometer, a rotating wheel used for measuring distances on map (Bohm, 1979). The data on plant height (cm), total tillers ($plant^{-1}$), leaf area $plant^{-1}$ (cm^2), dry weight per plant (mg), root length per plant (cm), root and shoot ratio and root dry weight per plant (mg) was recorded at 65 days after sowing. The plant height was measured with meter ruler from ground level to highest leaf tip. At harvest the front glass of rhizotron was removed and the soil was inverted on wooden pin board. The roots were carefully collected and were washed with water to remove sand material. The pin board had four horizons (0-30, 30-60, 60-90 and 90-120 cm). The total root mass in each horizon was collected separately for each genotypes to record the dry mass in different horizons. The roots and shoot material were kept under shade for sun drying and then were kept in electric oven at 80 ^{0}C for 48 hours for obtaining root and shoot dry weight. The roots and shoots were weighed separately on weight balance to measure the root-shoot ratio on dry weight basis. All the leaves from the plant were removed at harvest time and their area was determined on digital leaf area meter. The collected data on various shoot and root parameters were subjected to statistical analysis in Minitab statistical package. Where the treatment and interaction effects were found to be significant ($P<0.05$), the significance of treatments means were compared by using Fischer, s analysis of variance technique (Steel and Torrie, 1997).

RESULTS AND DISCUSSION

Shoot and root parameters:

Significant variations among the genotypes from both groups were identified for developmental traits like plant height, tillers, leaf area, dry weight of shoots and root length per plant and root-shoot ratio (Table 1). None of the tested varieties either from annual and perennial classes varied significantly for plant height. Furthermore, the below ground growth of annual genotypes was quite in accordance with plant height, hence both the traits were non significant. Although V3 was superior for tillering over rest of annual genotypes, the high tillering trait did not support leaf area development. The contribution of tillers for development of leaf area was not positive for annual genotypes but for perennial genotypes, it was not significant. So, it can be concluded that more tillers do not mean higher leaf area, as it is function of both leaf size and leaf number.

Table 1. Comparative studies of root and shoot of individual varieties from annual and perennial group

Treatment	Plant height (cm)		Total tillers per plant	
Varieties	Annual	Perennial	Annual	Perennial
V1	42.80 a LSD=8.4254	30.80 a LSD=6.8266	1.83 b LSD=0.9910	1.00 b LSD=0.6076
V2	45.00 a	32.90 a	2.00 b	2.05 a
V3	38.80 a	34.30 a	5.33 a	2.30 a
	Leaf area per plant (cm^2)		*Dry weight per plant (mg)*	
V1	68 c LSD=6.573	25.00 c LSD=5.8452	810 b LSD=24.712	159.00 c LSD=7.6317
V2	552 a	78.00 b	708 c	814.00 a
V3	218 b	125.00 a	1258 a	694.00 b
	Root length per plant (cm)		*Root shoot ratio*	
V1	110.20 a LSD=3.828	64.20 c LSD=8.4968	0.10 c LSD=0.0119	0.2033 a LSD=0.0200
V2	98.70 a	106.00 a	0.14 b	0.14 b
V3	109.70 a	91.20 b	0.21 a	0.14 b

The means in the table denoted by specific letters are significantly different at 5 % probability level.

From the perennial group, the V2 exceeded the tested varieties for dry weight and root length per plant. Its higher root length suggested it to be potential candidate for drought prone zones. Whereas more tillers and leaf area was observed from V3 and performance of V1 was poor for all tested traits except root to shoot ratio.

On the basis of growth habit evaluation, the perennial group produced the better figures for most of studied parameters (Figure 1a-f) but it did not mean they would produce more grains. There is presence of strong competitions for resource translocation between regrowth organs and grains production. The longer roots in perennials are crucial for regrowth and in second year, it may develop even better roots from reserved foods and established root system to support higher and early grains production over the first year. Jackson and Jackson (1999) also narrated the similar 2^{nd} year growth pattern. The production of longer roots is mainly associated with perennial wheat which is used for additional benefits like erosion control, gains in soil organic matter, wildlife habitats and regrowth. The above advantage from perennials are replacing annual particularly on marginal, drought and erosion prone zones of the world. But grains yield, regrowth and yield stability in successive years are major concerns of perennials which needs to be intensively studied. The production of shorter plants in perennials has also been confirmed by Jaikumar et al. (2012) who reported that first year perennial only achieved 78 % of annual wheat height. Rauf et al. (2006), Kashif (2010), Khafaga and Abd-Elnaby, 2007 and Khan et al. (2002) also reported wide variations in their studies on wheat genotypes seedling performance.

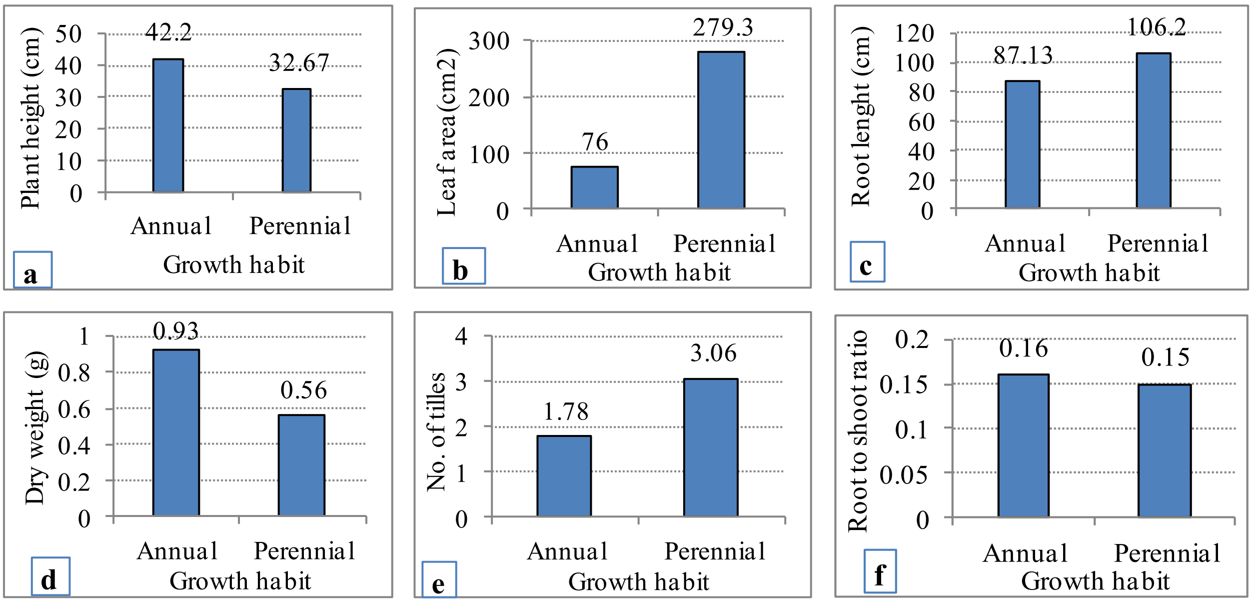

Figure 1 a-f. Plant height, leaf area, root length, dry weght, number of tillers per plant and root shoot ratio of annual vs perennial wheat

Root distribution pattern

The major portion of root mass was confined within 0-30 cm depth irrespective of growth habit. Beyond it was continuously reduced, and only 11.89 % and 8.07 % root mass of initial depth of annual and perennial wheat genotypes, respectively was found in 90-120 cm (Tables 2 & 3).

Table 2. Root dry weight (mg) of annual wheat genotypes at various soil depths

Varieties	0-30	30-60	60-90	90-120	Means
V1	49.40 b LSD=8.1165	23.60 cd	17.60 d	8.90 ef	24.87b LSD=4.0582
V2	42.10 b	28.4 c	17.00 de	3.1 f	22.65 b
V3	168.30 a	49.7 b	28.70 c	18.90 d	66.40 a
Means	86.60 a LSD=4.6861	33.90 b	21.10 c	10.30 d	

The means in the table denoted by specific letters are significantly different at 5 % probability level.

Table 3. Root dry weight (mg) of perennial wheat genotypes at various soil depths

Varieties	0-30	30-60	60-90	90-120	Means
V1	35.33 c LSD=7.2495	15.63 de	0.00 f	0.00 f	12.742 b LSD=3.6248
V2	49.90 b	32.43 c	21.20 d	12.80 e	29.083 a
V3	73.53 a	29.73 c	13.70 e	0.00 f	29.242 a
Means	52.92 a LSD=4.1855	25.933 b	11.63 c	4.27 d	

The means in the table denoted by specific letters are significantly different at 5% probability level.

Both the wheat group showed a gradual decrease in root mass with successive increase in soil depth (Figure 2). The varieties differed substantially for root mass and V3 in both the annual and perennial class produced the highest root mass in uppermost soil (0-30 cm). These results are in agreement with findings of studies conducted by Schweiger et al. (2009). It is suggested that wheat spread its major portion in top soil layers to increase the surface area for efficient use of nutrient and soil water. However, this may also favour the onset of early drought during vegetative development, even at low evapotranspiration demand. A similar trend in sorghum was documented by Jordan and Miller (1980). The root distribution of V2 from perennial was limited up to 30-60 cm and its complete failure for root penetration beyond 60 cm suggests its greater susceptibility for drought. The results are in agreement with Kinyua et al. (2003). According to Sato et al. (2006), the horizontal distribution of wheat roots can be explained by conical shape.

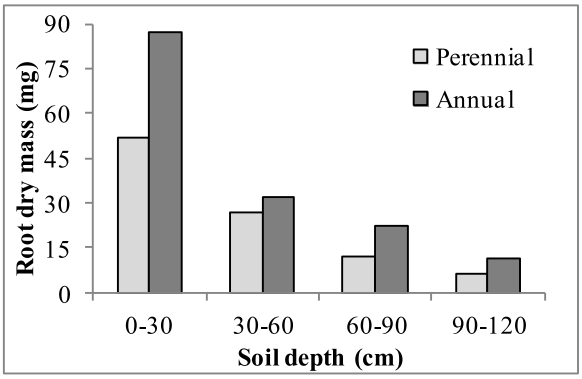

Figure 2. Root distribution pattern of annual and perennial wheat

Periodic root extension rate (cm)

The pattern of root extension rate was noted upto a period of eight weeks and it was observed at 7th week closely followed by first week (Figure 3). The lowest root extension rate was noted from 2nd to 6th week. However, the trend of periodic root development was quite similar in both the classes. The better understanding of root development with respect to time factor can play a significant role for better management of irrigation and nutrition programme. The period during stem elongation is the time of peak vegetative growth which coincides with rapid root growth, achieving maximum root extension when compared to earlier and later growth period. After anthesis, as reproductive parts are major sink for photo assimilates, hence no significant onward root growth from 7th week was observed in the study.

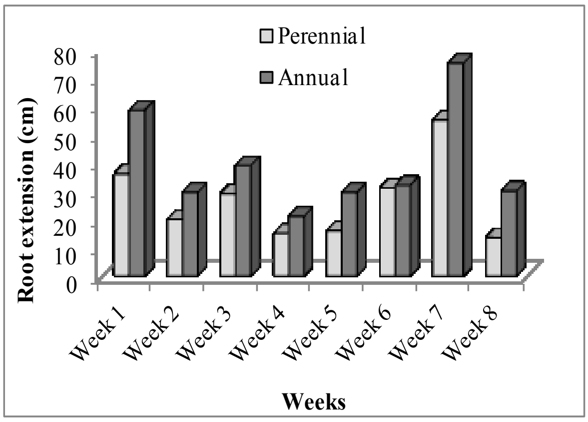

Figure 3. Week wise root extension of annual and perennial wheat

CONCLUSION

The prevailing genotypic and growth habit variations suggested that like above ground growth, significant variations are also common in hidden plant parts and must be taken into consideration for better resource utilization. The strong association between downward and upward plant growth characters suggests the need of more intensive experimentation on root behaviour for utilizing the hidden potential of the crop. The perennial wheat exceeded the annual for studied traits but pattern of root development was similar. The use of perennials as an alternate grain crop over annuals will require intensive investigation on economic and ecological perspective.

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