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Impact of Awn Removal on Grain Weight, Number and Yield of Wheat Genotypes Under Terminal Water Stress Conditions

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Abstract

Annual genetic increase in wheat is around 1.6 and required to be doubled to sustainably produce wheat for 9 billion people till 2050. To increase grain number and grain weight breeders need to concentrate on different traits to reduce partitioning to other traits and divert assimilates to grain. Present work was conducted in BARDC Balochistan to study the influence of awns on grain yield, grain numbers and grain weight under terminal water stress condition. All genotypes were de-awned at anthesis and were compared to awned spikes of the same genotypes. Awn's removal had significant impact on grain weight where 1000 kernel weight data showed higher grain weight (32.9 – 58.2) with awns removed at anthesis stage as compared to similar genotype with awns which ranged from 30.3 to 50.0 grams. In contrast, the grain number was reduced in spikes where awns were removed while awns showed positive impact on grain number in the study under terminal drought. Significant ($p<0.05$) variability was observed for different morphological traits under study including biological yield, Days to 50% heading, Number of tillers per plant, Grain yield, harvest index, Grain number, spike length, spike chaff length in awn-letted and spike length in awned genotypes. Furthermore, mean comparison highlighted a relatively higher range of Spike weight, Grain number, Grain weight per spike in awned varieties compared to awn-letted. In contrary to that, final data attributed to the fact that removal of awns may have contributed to relatively higher range of 1000 kernel weight, Spike length, Spike chaff weight in awnless compared to awned varieties. Overall results further confirmed a positive correlation between grain number and grain weight associated traits in awn-letted varieties. It was concluded that awns play important role in final grain yield and its manipulation may prove to be positive in increasing grain number and weight which will indirectly increase grain yield.

Keywords: Wheat Genotype; Awns; Morphological Traits; Yield

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Introduction:

Wheat (*Triticum aestivum* L.) is one of the important cash crops in the world, covering 237 million hectares annually, giving off total 420 million tonnes (Isitor *et al.,*1990; Langer & Hill, 1991; Olabanji *et al.,* 2004). Pakistan is one of the largest producers of wheat crop while occupying eighteenth rank in world wheat production list. In Pakistan extensive production of wheat as staple and food security crop is carried out to feed large growing population. As the human population increases, the pressure to meet basic food requirement will also increases. At present, large population globally depends upon wheat for approximately one fifth of their nutritional requirement (21% calories and 20% protein), which indicates worth of this important crop for global food security (Shiferaw *et al.,* 2013). It has been pointed out that global wheat requirement is predicted to enhance by about 1.6% per year while it will be 2% annually in developing countries like Pakistan (Rosegrant *et al*., 1994). By 2050 wheat demand is expected to increase by 60% and wheat yield increases must effectively double to cater the demand (Ray *et al*., 2013). Therefore, the world average wheat yield needs to be doubled to meet growing demand. The rate of genetic yield development is too low to achieve desired results (Sayre *et al*., 1997). Multi-dimensional research efforts will be required to meet the future wheat demand. Development of abiotic stress tolerant crops and introgression of source and sink traits to increase yields are few of the crucial areas of consideration. Abiotic stresses including drought, salinity and heat greatly limit the wheat yield and it is estimated that single degree increase in temperature will cause 6 % reduction in wheat production (Asseng *et al.,* 2015). Wheat breeders are therefore challenged with the difficult task to improve yield and quality under rapidly changing climatic conditions (Anderegg *et al*., 2020). In recent times, environmental catastrophes due to anthropogenic activities is making it more challenging task to find suitable genotypes (Araus *et al.,* 2008). Drought, being a yield-limiting factor, has become a major threat to international food security (Mohammadi *et al*., 2018). Wheat grain yield is one of the major factors impacted by drought at different growth stages. The grain yield is quantitative trait and strongly related to number of grains and grain weight (Rodriguez *et al*., 2019). Genetic advances for high yield and grain value while sustaining crop quality under environmental pressure has received great consideration (Oliveira *et al*., 2011). Major improvement in wheat yield is credited to increases in the number of grains per unit area (Perry & D'Antuono *et al*., 1989; Sayre *et a*l. 1997; Fischer *et al*., 2007) and partitioning of biomass to grains (higher harvest index) which was made possible by decreasing wheat plant height using dwarfing genes (Austin *et al*.,1980). To increase sink (reproductive parts) researchers emphasized on the manipulation of sinks and sources as wheat is sink-limited and that increasing the sink capacity would increase the yield potential (Fischer *et al*., 2007; Miralles & Slafer 2007; Reynolds *et al*., 2007). Growing cultivars with excellent adaption to water limited environment is difficult because of complex interactions between genotype and environment, resulting a change in adaptation pattern of different genotypes under different environmental conditions (Cooper *et al.,* 2001; Richards *et al*., 2002). Different agronomic traits anticipated as key factors linked with yield potential of a wheat crop. A genotype with a higher yield potential will ultimately translate into higher performance under drought condition thus, empirical selection and propagation of wheat variety will help to cope with growing demands of food for future generation in developing counties such as Pakistan. It has been noticed that selection efficiency for higher yield is dependent to the knowledge of plant morphological traits and their interaction with grain yield (Ali *et al.,* 2014abcd; Awan *et al.,* 2015; Naseem *et al.,* 2015ab; Saeed *et al.,* 2014; Khan *et al.,* 2014; Masood *et al.,* 2015ab; Waseem *et al.,* 2014; Zameer *et al.,* 2015ab; Bibi *et al.,* 2015). Awn is an important morphological character which is a hair-like appendage and have shown to contribute to photosynthesis and providing assimilates of grain filling thus appeared to have a vital role in final grain yield especially in drought conditions. Awn seems to influence agronomic performance of crops but varies with the variation in genetic and climatic factors (Ntakirutimana & Xie, 2020).

1.1. Objectives:

- To highlight potential role of awns on morphological traits and.
- To explore the final grain yield while documenting genotypic variability with suitable yield and favorable traits under terminal water stress condition.

2. Materials and Methods:

2.1. Study Area:

The research work was completed in Balochistan Agriculture Research and Development center (BARDC) Quetta during the year 2020-2021 which is a semi-arid region. The research consisted of 22 genotypes with two check varieties (Table 1).

Table 1: List of Wheat genotypes studied in present work

S. No.	Code	S. No.	Code
1	BARDC-W1	12	BARDC-W12
2	BARDC-W2	13	BARDC-W13
3	BARDC-W3	14	BARDC-W14
4	BARDC-W4	15	BARDC-W15
5	BARDC-W5	16	BARDC-W16
6	BARDC-W6	17	BARDC-W17
7	BARDC-W7	18	BARDC-W18
8	BARDC-W8	19	BARDC-W19
9	BARDC-W9	20	BARDC-W20
10	BARDC-W10	21	BARDC-W21
11	BARDC-W11	22	BARDC-W22

2.2. Experimental Layout:

Experiment was laid down in alpha lattice design with two replications and planted in the mid of November and harvested in May. Each plot comprised of 4 rows of 4 meter long and row to row distance was kept at 25 cm. All agronomic practices (irrigation and fertilizer application) were kept same for all genotypes. To check the impact of awns on different yield related traits 10 awns per plot were randomly selected and awns were removed by excision (cutting awns through scissor).

2.3. Examination of Morphological Traits:

Following morphological traits were examined, Plant Height (PH), Biological Yield (BY) from whole plot, Dry Spike Weight awned (SW-AWD), Dry Spike Weight awn-letted (SW-AWL), Days to Heading (DTH), Grain Number of 10 Spike Awned (GN-AWD), Grain Number of 10 Spike Awn-letted (GN-AWL), Grain yield (GY), Grain weight mature Spike awned (GWS-AWD), Grain weight mature Spike awn-letted (GWS-AWL), Grain weight/Grain number awned (GW/GN-AWD), Grain weight/Grain number awn-letted (GW/GN-AWL), Harvest Index (HI), 1000 Kernel weight of awned (KWT-AWD), 1000 Kernel weight of awn-letted (KWT-AWL), Spike Length awned (SL-AWD), Spike Length awn-letted (SL-AWL), Spike Chaff weight awned (SCW-AWD), Spike Chaff weight awn-letted (SCW-AWL), Number of tillers (No. tiller).

2.4. Statistical Analysis:

For statistical analysis of morphological characters analysis of variance (ANOVA) was carried out according to steel *et al*. (1997) and means were compared at 5 %LSD. Correlation coefficient among yield and yield related characters was estimated.

3. Results:

The present study, thus; was designed to study the impact of awn excision on grain numbers, grain weight and indirect effect on grain yield in different wheat genotypes to manipulate source and sink partitioning under terminal water stress conditions. The experiment was conducted at Balochistan Agriculture Research and

Development Center (BARDC) Quetta. To evaluate the germplasm in the study two treatments were performed a. control (genotypes with awns) and b. Awn-letted (removal of awns from 10 spikes at anthesis) of each genotype to check the impact of awn removal on final yield and yield related traits. Likewise, different morphological traits *viz.,* Plant height (PH), Biological Yield (BY), Dry Spike Weight (awned and awn-letted), Days to heading (DTH), Grain Number of 10 Spike Awned and awn-letted (GN-AWD, GN-AWL), Grain Number of 10 Spike awned and awn-letted (GN-AWD, AWL), Grain yield (GY), Grain weight mature Spike awned and awn-letted (GWS-AWD and AWL), single grain weight for awn and awn-letted treatment, Harvest Index (HI), 1000 Kernel weight for both treatments (awned and awn-letted), Spike Length awned and awn-letted (SL-AWD and SL-AWL), Spike Chaff weight awned and awn-letted (SCW-AWD, SCW-AWL), Number of tillers (No. tiller) were also investigated to check the correlation between traits among 22 wheat genotypes (Table 2).

Table 2: Rainfall, maximum and minimum temperature in wheat during 2020-21 cropping season

Months	Max-Temperature	Min-Temperature	Rainfall (mm)
November	26.11	-1.4	20.28
December	23.5	-8.2	5.5
January	21.1	-8.6	0.0
February	24.4	-2.3	1.27
March	29.2	-0.7	32.25
April	35.4	5.2	4.55
May	35.9	13.3	10.0

The results of analysis of variance showed a significant difference ($p<0.05$) in different morphological traits including BY, DTH, GN-AWL, GY, HI, SL-AWD, SL-AWL, SCW-AWL and No. tiller among investigated genotypes (Table 2). Other results highlighted a difference yet non-significant at $p<0.05$ for traits such as PH, SW-AWD, SW-AWL, GN-AWD, GWS-AWD, GWS-AWL, GW/GN-AWD, GW/GN-AWL, KWT-AWD, KWT-AWL, SCW-AWD among genotypes studied in present work (Table 3). Dry spike weight (SW) in control varieties with awns ranged 16.5 (BARDC W-3) to 10.7 (BARDC W-18) g whereas, awn-letted varieties exhibited a range of 15.1 (BARDC W-22) to 7.8 (BARDC W-14) showing a reduction in weight due to removal of awns. The percentage decrease observed after de-awning in SW in selected varieties. Grain Number of 10 spike (GN) with awns ranged from 245.5 (BARDC W-9) to 175.5 (BARDC W-17) while awn excision led to observe a lower range *viz.,* 202.5 (BARDC W-13) to 107 (BARDC W-14) in awn-letted. The percentage reduction in the GN after de-awning was evident. Other traits such as Grain weight mature spike (GWS) also showed a higher range in control varieties *viz.,* 11.6 (BARDC W-3) to 5.1 (BARDC W-17) as compared to awn-letted *viz.,* 9.1 (BARDC W-4) to 4.5 (BARDC W-14). The percentage decrease in the GWS after de-awing. These finding indicated that a pronounced effect of awn excision on SW, GN, GWS traits (Table 4).

Table 3: Analysis of Variance (ANOVA) for morphological traits in wheat genotypes

S. No.	Traits	DF	SS	MS	F	P
1	Plant Height (PH)	21	907.75	43.226	1.46	0.1953
2	Biological Yield (BY)	21	6.0846	0.28974	3.44	0.0033
3	Dry Spike Weight (SW) Awned	21	92.242	4.39247	0.68	0.8043
4	Dry Spike Weight (SW) Awn-letted	21	184.636	8.792	1.51	0.1750
5	Days to Heading 50% (DTH)	21	238.727	11.3680	6.19	0.0001
6	Grain Number of 10 Spike (GN) Awned	21	15317.5	729.40	0.24	0.9991
7	Grain Number of 10 Spike (GN) Awn-letted	21	35522.5	1691.5	2.05	0.0544
8	Grain yield (GY)	21	0.48740	0.02321	3.04	0.0070
9	Grain weight mature Spike (GWS) Awned	21	78.079	3.71807	0.88	0.6113
10	Grain weight mature Spike (GWS) Awn-letted	21	66.050	3.1452	1.04	0.4625
11	Grain weight/Grain number (GW/GN) Awned	21	0.00130	6.175E-05	1.80	0.0930
12	Grain Weight/Grain number (GW/GN) Awn-letted	21	0.00178	8.498E-05	1.20	0.3388

13	Harvest Index (HI)	21	431.117	20.529	2.51	0.0201
14	1000 Kernel weight of awned **(**KWT) Awned	21	1296.81	61.7527	1.80	0.0930
15	1000 Kernel weight of **(**KWT) Awn-letted	21	1784.56	84.979	1.20	0.3388
16	Spike Length (SL) Awned	21	23.7255	1.12978	2.29	0.0319
17	Spike Length (SL) Awn-letted	21	33.2039	1.58114	2.26	0.0341
18	Spike Chaff weight (SCW) Awned	21	69.605	3.31454	0.97	0.5298
19	Spike **C**haff weight **(**SCW) Awn-letted	21	92.688	4.4137	2.16	0.0427
20	No. tiller **(**No tiller)	21	13047.7	621.32	2.51	0.0204

Among other morphological yield related traits, 1000 kernel weight (KW-AWD) in control varieties a relatively lower range was observed (50.0 to 28.5) in BARDC-W3 and BARDC W-19 respectively whereas, awn-letted varieties exhibited a range of 58.2 (BARDC W-8) to 32.9 (BARDC W-13). An increase in the KW after de-awning was found. Likewise, spike length (SL) in control varieties ranged 9.7 (BARDC W-21) to 8.0 (BARDC W-2,4,12,14 and 18) and awn-letted varieties ranged from 11.0 (BARDC W-10) to 7.5 (BARDC W-20) indicating a percentage rise in the SL after de-awning. Spike chaff weight (SCW) was observed in a range of 8.1 (BARDC W-13) to 2.5 (BARDC W-18) in control whereas in awn-letted a range of 9.4 (BARDC-W-22) to 3.0 (BARDC- W-6) was recorded highlighting an improvement in SCW after de-awning. These overall findings attributed to the fact that removal of awns may have contributed to relatively higher range of KW (Figure 1).

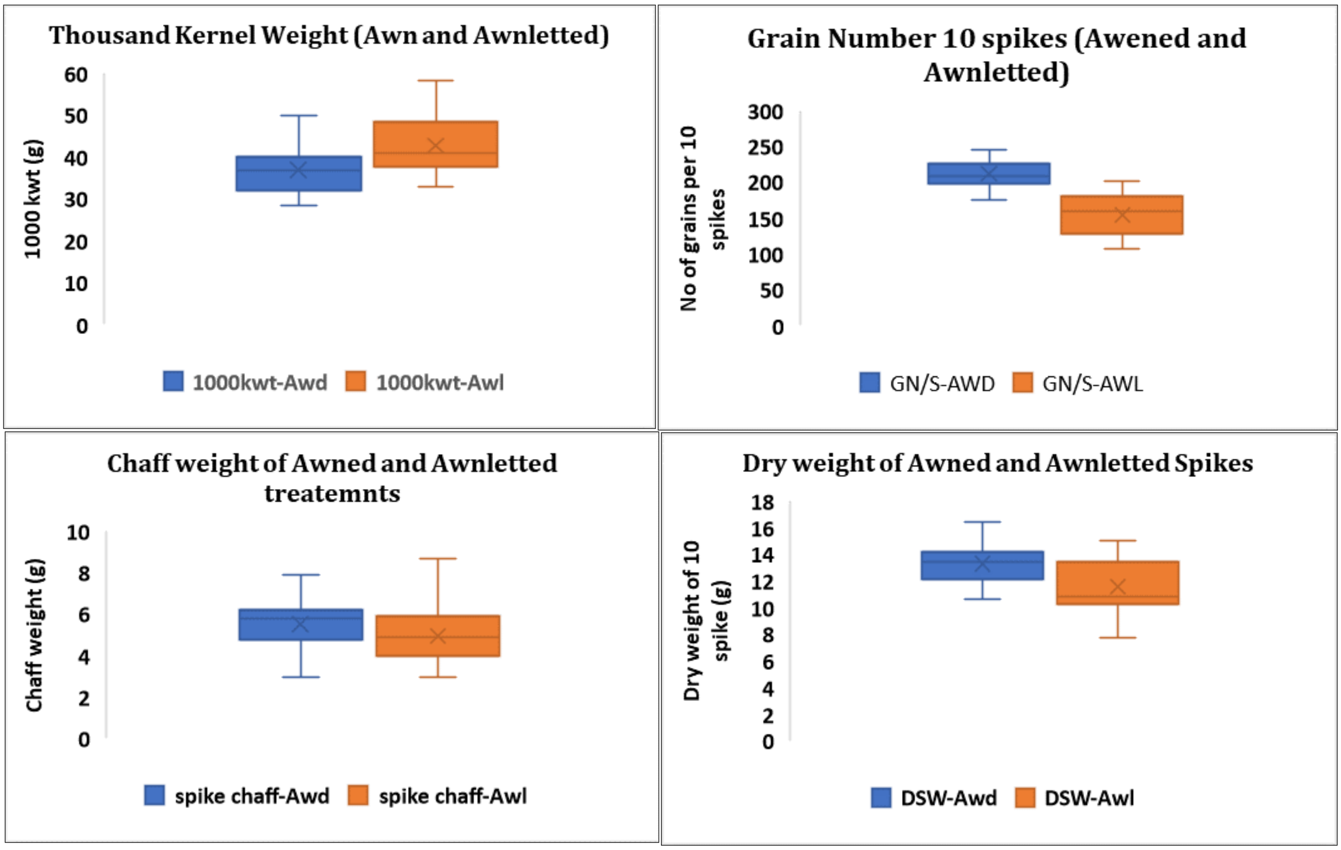

Figure 1: Boxplot of a. Thousand Kernel weight and b. grain number per 10 spikes of Awned and Awn-letted treatments c. chaff weight and d. dry weight of spikes

SL, SCW in awn-letted compared to control varieties (Table 4). Statistical analysis of data showed significant differences in other traits as well i.e., for days to 50 % heading among wheat lines minimum DTH was recorded in BARDC-W-10 (127.5) whereas maximum DTH was recorded in BARDC-W-9, BARDC-W-11 and BARDC-W-14 (135.5) showing a better performance under terminal water stress among all investigated wheat line followed by BARDC-W-22 (134.5) and BARDC-W-7 (133) whereas the. Early maturity help crop in escaping drought stress but due to drought stress and desiccating winds during grain filling period in study area early maturity had negative impact on grain yield by forcing maturity. Further results indicated that genotype BARDC-W-11 showed a maximum plant height (68.6 cm) compared to other genotypes, otherwise followed by BARDC-W-4 (64) and BARDC-W-2 (63.8) and a minimum plant height of 50.1 cm was recorded in BARDC-W14. Statistical analysis further unveiled a significant difference for grain yield among 22 genotypes. The results showed a maximum grain yield (0.537) in BARDC-W-15 followed by BARDC-W-22 (0.517) and a minimum grain yield of 0.150 kg plot^{-1} was quantified in BARDC-W-3, BARDC-W-1 (0.187) and BARDC-W-2 (0.197), respectively. Wheat genotypes further deciphered significant differences comparatively in their biological yields under terminal water stresses. Analyzed data revealed that BARDC-W22 showed a maximum biological yield (2.6) followed by BARDC-W-20 (20), BARDC-W-13, BARDC-W-15, and BARDC-W-17 (1.9). A minimum biological yield was recorded in BARDC-W-3 (0.9).

The results obtained showed variations in harvest index (HI) of different wheat genotypes. Among investigated genotypes, BARDC-W-15 showed a maximum HI of 27.5. whereas other genotypes such BARDC-W-19 with 26.2 BARDC-W-13 with 24.9 and BARDC-W-5, BARDC-W-17 with 24.3 showed a good HI within entire investigated line. BARDC-W-3 showed a minimum of 15.3 HI. Harvest index is major trait of green revolution where plant height reduction resulted in higher grain yield improving HI%. Further HI improvement is unlikely and major improvement will come from efficient utilization of current biomass and better partitioning of assimilates to grain. Analysis of the data further revealed that higher productive tillers per meter square were 91 tillers and recorded in BARDC-W-2 followed by BARDC-W-6 (86.5) and BARDC-W-8 (83), while lower no of tiller were recorded in BARDC-W-14 (Table 3). Finding broadly emphasized that among 22 genotypes BARDC-W15 exhibited a relatively good biological yield, grain yield and harvest index. Maximum number of tillers and plant higher were observed in BARDC-W2 and BARDC-W11 respectively (Table 5).

Table 4: Means values for different morphological traits of awned and awnless wheat genotypes.

Genotype	Dry spike Weight (SW)		Grain Number of 10 spike (GN)		Grain weight mature spike (GWS)		Grain weight/Grain number (GW/GN)		1000 Kernel weight (KWT)		Spike Length (SL)		Spike Chaff weight (SCW)	
	Awned	Awn-letted	**Awned**	Awn-letted	**Awned**	Awn-letted	**Awned**	Awn-letted	**Awned**	Awn-letted	**Awned**	Awn-letted	**Awned**	Awn-letted
BARDC-W1	10.9 B	10.6 ABCD	220.0 A	167.0 ABCDE	7.2 B	5.9 AB	0.03 CDE	0.03 AB	33.2 CDE	35.5 CD	9.5 BC	8.5 DEFG	3.6 BC	4.6 BCDE
BARDC-W2	12.3 AB	13.0 ABC	199.0 A	201.5 A	8.3 AB	7.1 AB	0.04 ABCD	0.03 AB	42.2 ABCD	35.4 CD	8.0 BC	9.1 BCDEFG	3.9 BC	5.9 BCDE
BARDC-W3	16.5 A	13.7 ABC	235.5 A	181.5 ABC	11.6 A	6.7 AB	0.05 A	0.03 AB	50.0 A	38.5 BCD	9.3 ABC	8.6 CDEFG	4.9 ABC	7.0 AB
BARDC-W4	14.7 AB	15.0 A	215.0 A	182.5 ABC	8.7 AB	9.1 A	0.04 ABCDE	0.05 A	40.5 ABCDE	50.7 ABC	8.0 ABC	7.6 FG	6.0 ABC	5.8 BCDE
BARDC-W5	13.1 AB	14.8 AB	205.50 A	187.5 AB	7.4 AB	8.6 A	0.03 BCDE	0.04 A	36.2 BCDE	45.4 ABCD	8.1 ABC	8.2 EFG	5.7 ABC	6.2 BC
BARDC-W6	14.0 AB	9.3 CD	209.0 A	165.0 ABCDE	8.1 AB	6.3 AB	0.03 ABCDE	0.03 AB	38.5 ABCDE	38.3 BCD	9.5 ABC	9.8 ABCDE	5.8 ABC	3.0 E
BARDC-W7	13.7 AB	11.7 ABCD	243.5 A	156.0 ABCDE	7.9 AB	7.6 AB	0.03 CDE	0.04 AB	33.2 CDE	49.3 ABCD	8.8 ABC	10.6 AB	5.8 ABC	4.1 BCDE
BARDC-W8	14.1 AB	12.0 ABCD	196.0 A	114.0 DE	9.0 AB	6.6 AB	0.04 AB	0.05 AB	46.4 AB	58.2 A	8.8 ABC	9.2 BCDEFG	5.0 ABC	5.4 BCDE
BARDC-W9	15.1 AB	10.8 ABCD	245.5 A	115.5 DE	9.2 AB	4.7 B	0.03 BCDE	0.04 B	37.5 BCDE	41.1 ABCD	8.5 ABC	9.3 ABCDEF	5.8 ABC	6.0 BCD
BARDC-W10	13.3 AB	10.8 ABCD	202.5 A	126.0 CDE	6.4 B	5.9 AB	0.03 DE	0.04 AB	31.0 DE	48.2 ABCD	11.0 AB	11.0 A	6.9 AB	4.9 BCDE

LSD	BARDC-W22	BARDC-W21	BARDC-W20	BARDC - W19	BARDC - W18	BARDC - W17	BARDC-W16	BARDC-W15	BARDC - W14	BARDC - W13	BARDC - W12	BARDC-W11
5.26	13.7 AB	11.9 AB	13.4 AB	11.1 B	10.7 B	11.3 AB	13.2 AB	13.7 AB	12.9 AB	15.0 AB	13.6 AB	14.6 AB
5.013	15.1 A	13.4 ABC	9.8 BCD	10.5 ABCD	10.5 ABCD	9.0 CD	13.2 ABC	13.7 ABC	7.8 D	10.8 ABCD	9.1 CD	11.0 ABCD
115.3	222.5 A	215.0 A	241.0 A	209.0 A	192.5 A	175.5 A	212.5 A	240.5 A	205.5 A	195.0 A	205.0 A	190.0 A
59.81	130.0 BCDE	152.5 ABCDE	132.0 BCDE	144.0 ABCDE	168.5 ABCD	134.5 BCDE	189.0 AB	162.5 ABCDE	107.5 E	202.5 A	123.5 CDE	167.5 ABCD
4.268	7.1 B	8.1 AB	7.2 B	5.9 B	8.1 AB	5.1 B	8.0 AB	9.1 AB	9.1 B	6.9 B	6.1 B	8.3 AB
3.612	5.7 AB	7.2 AB	6.2 AB	6.0 AB	7.3 AB	5.6 AB	7.8 AB	8.7 A	4.5 B	6.4 AB	4.9 B	6.0 AB
0.012	0.03 CDE	0.03 ABCDE	0.03 DE	0.02 E	0.04 ABCDE	0.03 DE	0.03 ABCDE	0.03 ABCDE	0.03 BCDE	0.03 BCDE	0.03 DE	0.04 ABC
0.01	0.04 AB	0.04 AB	0.04 AB	0.04 AB	0.03 AB	0.04 AB	0.04 AB	0.05 A	0.04 B	0.03 AB	0.03 B	0.03 AB
12.17	32.2 CDE	38.7 ABCDE	30.6 DE	28.5 E	40.0 ABCDE	31.4 DE	39.2 ABCDE	38.6 ABCDE	35.7 BCDE	34.7 BCDE	30.3 DE	43.9 ABC
17.48	43.9 ABCD	48.9 ABCD	47.5 ABCD	40.1 BCD	39.8 BCD	40.3 BCD	40.9 ABCD	54.0 AB	41.6 ABCD	32.9 D	36.4 BCD	36.4 CD
1.45	9.3 AB	9.7 BC	8.1 ABC	8.6 ABC	8.0 C	9.3 ABC	9.0 ABC	8.5 ABC	8.0 ABC	8.8 A	8.0 AB	9.2 ABC
1.73	10.0 ABCD	8.6 CDEFG	7.5 CDEFG	9.3 ABCDEF	9.5 ABCDE	8.6 CDEFG	8.7 CDEFG	8.6 CDEFG	8.3 DEFG	9.0 BCDEFG	10.3 ABC	9.0 BCDEFG
3.84	6.5 AB	3.8 BC	6.1 ABC	5.1 ABC	2.9 C	6.2 ABC	5.2 ABC	4.5 ABC	5.9 ABC	8.1 AB	7.4 AB	6.3 ABC
2.97	8.7 A	6.1 BC	3.6 CDE	4.4 BCDE	3.1 DE	3.4 CDE	5.4 BCDE	4.9 BCDE	3.3 CDE	4.3 BCDE	4.2 BCDE	4.9 BCDE

S. E	1.79	1.7045	39.217	20.336	1.4513	1.2282	0.00414	0.00595	4.14	5.94	0.49	0.59	1.3088	1.0114
Probability	N. S	N. S	N. S	*	N. S	N. S	N.S	N. S	***	N.S	**	**	N.S	**
CV	19	20.7	26.1	18.6	26.3	26.2	15.8	19.5	15.8	19.5	7.95	9.2	33.4	28.4
Grand mean	13.36	11.67	212.5	155	7.811	6.625	0.037	0.043	36.98	43.05	8.832	9.084	5.548	5.044

Means sharing the same case letter for main effects do not differ significantly at p < 0.05

Table 5: Means values for different morphological traits of wheat genotypes.

Genotype	Harvest index (HI)	Days to Heading (50%) (DTH)	Number of Triller of Plants (No tiller)	Plant Height (cm) (PH)	Biological Yield (BY) kg plot^{-1}	Grain Yield (GY) kg plot^{-1}
BARDC-W1	15.4 F	130.5 DEFGHI	55.5 BCDE	58.2 ABCD	1.2 FGH	0.18 HI
BARDC-W2	17.8 EF	132.0CDEF	91.0 A	63.8 ABC	1.0 GH	0.19 GHI
BARDC-W3	15.3 F	132.0 CDEF	65.5 ABCDE	60.8ABCD	0.9 H	0.15 I
BARDC-W4	22.6 ABCDE	132.0 CDEF	71.5 ABCD	64.0 AB	1.4 CDEFGH	0.33 BCDEFGH
BARDC-W5	24.3 ABCD	130.50 DEFGHI	81.0 AB	61.0ABCD	1.3 EFGH	0.32 BCDEFGHI
BARDC-W6	19.7 CDEF	129.0 GHIJ	86.5 ABC	59.8 ABCD	1.5 BCDEFG	0.33 BCDEFGH
BARDC-W7	20.8 BCDEF	133.0 ABCD	63.5 ABCDE	59.8 ABCD	1.2 FGH	0.26 FGHI
BARDC-W8	20.2 CDEF	130.0 EFGHIJ	83.0 ABC	60.6 ABCD	1.3 CDEFGH	0.30 CDEFGHI
BARDC-W9	19.3 CDEF	135.0 AB	71.0 ABCD	52.7 BCD	1.2 FGH	0.27 EFGHI
BARDC-W10	19.9 CDEF	127.5 J	58.0 BCDE	59.5 ABCD	1.3 DEFGH	0.28 DEFGHI
BARDC-W11	18.7 DEF	135.0 AB	68.5 ABCD	68.6 A	1.5 BCDEFGH	0.310 CDEFGHI
BARDC -W12	23.2 ABCDE	128.5 HIJ	42.0 DEF	57.0 BCD	1.3 EFGH	0.312 CDEFGHI
BARDC -W13	24.9 ABC	132.5 BCDE	35.5 EF	57.0 BCD	1.9 BCD	0.49 AB
BARDC -W14	22.4 ABCDE	135.5 A	17.5 F	50.1 D	1.6 BCDEFG	0.37 ABCDEFG
BARDC-W15	27.5 A	131.5 DEFG	55.0 BCDE	59.1 ABCD	1.9 BC	0.53 A
BARDC-W16	23.7 ABCDE	129.5 FGHIJ	55.5 BCDE	53.0 BCD	1.5 BCDEFGH	0.37 ABCDEFG
BARDC -W17	24.3 ABCD	132.0 CDEF	43.0 DEF	52.6 CD	1.9 BCDE	0.47 ABC
BARDC -W18	21.0 BCDEF	128.5 HIJ	47.0 DEF	53.8 BCD	1.7 BCDEF	0.37 ABCDEFG
BARDC -W19	26.2 AB	128.0 IJ	51.5 CDE	57.2 BCD	1.7 BCDEF	0.46 ABCD
BARDC- W20	20.8 BCDEF	131.0 DEFGH	53.0 CDE	50.8 D	2.0 AB	0.45 ABCDE
BARDC-W21	22.2 ABCDE	129.0 GHIJ	60.5 ABCDE	54.8 BCD	1.8 BCDEF	0.427 ABCDEF
BARDC-W22	18.4 DEF	134.5 ABC	47.500 DEF	54.0 BCD	2.6A	0.517 A
LSD	5.9442	2.8175	32.747	11.30	0.60	0.18
S.E.	2.0211	0.9580	11.135	0.94	0.20	0.06
F- Probability	***	***	**	N. S	***	**
CV	13.38	1.03	26.59	1.01	18.31	24.83
Grand mean	21.358	131.23	59.227	131.7	1.58	0.35

Means sharing the same case letter for main effects do not differ significantly at p < 0.05.

Among other measured traits, number of tillers (No. tiller) showed a significantly positive correlation with plant height (r =0. 64). Spike weight, grain weight per spike, grain number and 1000 kernel weight of awned genotypes showed negative correlation with biological yield, grain yield and harvest index while awn-letted genotypes showed medium to low positive correlation to BY, GY and HI (Table 6). We also observed that spike length (0.28), SW (0.30), grain weight per spike (0.36) spike chaff weight (0.12) and grain number (0.20) has medium to low correlation with awned and awn-letted treatment which shows that the major effect is due to drought and the treatment implemented. The results showed that spike weight (SW-Awn-letted) showed positive high to medium correlation with all of traits except spike length awn-letted (SL-AWL) which shoed negative correlation due to awn excision (Table 6). This make spike weight an important trait to be used during selection of germplasm under drought conditions. BY showed positively significant association with GY (r= 0.94) and harvest index showing that biomass has significant impact on final grain yield under terminal drought conditions. Similarly, GY exhibited positive correlation to HI (r= 0.79). Biological yield has profound impact on developing stem reserves and positive relationship with grain yield.

Table 6: Correlation coefficient for different morphological traits

Traits	DTH	No-Tiller	PH	SL-AWD	SL-AWL	SW-AWD	SW-AWL	GWS-AWD	GWS-AWL	SCW-AWD	SCW-AWL	GN-AWD	GN-AWL	GW /GN-AWD	GW/ GN-AWL	KWT-AWD	KWT-AWL	BY	GY	HI
DTH	1.00																			
No-Tiller	-0.02	1.00																		
PH	0.06	0.64	1.00																	
SL-AWD	-0.14	0.19	0.11	1.00																
SL-AWL	-0.26	-0.10	-0.06	0.28	1.00															
SW-AWD	0.25	0.07	0.24	0.20	0.03	1.00														
SW-AWL	0.00	0.48	0.47	0.17	-0.14	0.30	1.00													
GWS-AWD	0.15	0.14	0.13	0.03	-0.08	0.64	0.31	1.00												
GWS-AWL	-0.17	0.37	0.50	0.03	-0.16	0.27	0.81	0.36	1.00											
SCW-AWD	0.16	-0.06	0.15	0.22	0.13	0.57	0.04	-0.26	-0.04	1.00										
SCW-AWL	0.18	0.40	0.25	0.24	-0.06	0.20	0.79	0.13	0.29	0.12	1.00									
GN-AWD	0.15	-0.08	-0.01	0.04	0.02	0.51	0.26	0.66	0.35	-0.07	0.07	1.00								
GN-AWL	-0.07	0.34	0.47	0.08	-0.27	0.28	0.58	0.35	0.70	-0.02	0.21	0.20	1.00							
GWT/GN-AWD	0.07	0.27	0.18	-0.02	-0.18	0.31	0.13	0.62	0.12	-0.28	0.09	-0.16	0.23	1.00						
GWT/GN-AWL	-0.11	0.18	0.22	0.01	0.07	0.19	0.49	0.19	0.58	0.03	0.20	0.32	-0.15	-0.06	1.00					
KWT-AWD	0.07	0.27	0.18	-0.02	-0.18	0.31	0.13	0.62	0.12	-0.28	0.09	-0.16	0.23	1.00	-0.06	1.00				
KWT-AWL	-0.11	0.18	0.22	0.01	0.07	0.19	0.49	0.19	0.58	0.03	0.20	0.32	-0.15	-0.06	1.00	-0.06	1.00			
BY	0.11	0.07	0.08	0.15	-0.10	-0.05	0.29	-0.23	0.26	0.18	0.21	-0.01	0.19	-0.28	0.14	-0.28	0.14	1.00		
GY	0.06	0.16	0.11	0.13	-0.15	-0.07	0.30	-0.28	0.30	0.21	0.17	-0.07	0.23	-0.28	0.15	-0.28	0.15	0.94	1.00	
HI	-0.02	0.25	0.11	0.02	-0.20	-0.13	0.22	-0.34	0.26	0.20	0.08	-0.19	0.18	-0.25	0.14	-0.25	0.14	0.55	0.79	1.00

4. Discussion:

A number of studies have highlighted the potential of awns to improve photosynthetic capacity to increase wheat performance Rebetzke *et al*. (2016). Moreover, Awns play important roles in seed dispersal, protection against predators, and photosynthesis Liu *et al*. (2021). Similar were the findings of Gashaw *et al.* (2010) and Thanna *et al*. (2011), reported a significant variation among different wheat genotypes for different yield related traits.

These results are in agreement with the previously reported studies that observed a difference in yield related traits between awned and awn-letted varieties in several cereal crops including wheat (Duwayri *et al*., 1984; Maydup *et al*., 2014; Huo *et al*., 2017). Duwayari *et al*. (1984) reported reduction in grain number, grain weight and final grain yield after excision of awns, flag leaf and its combination in durum wheat. In contrast, Bruening *et al*. (2019) reported higher test weight for awn-less genotypes in 10-year study. In a study conducted by Rebetzke *et al*. (2016) showed that awns reduced grain number to increase grain size while it had negative impact on grain number which is in contrast to over results where awn-letted (Awn-less) treatment produced higher grain weight (1000 KWT) under terminal drought stress conditions. The heavier grain may be due to the transfer of stem reserves and photo assimilates to grain better than its partitioning to different spike components after excision of awns. Similarly, Blum *et al*. (1998) reported that dry matter reserves in the stem and its translocation to grains considerably increases under drought stress condition.

Plant height is heavily study trait and played important role in green revolution by reducing wheat height to provide higher assimilates to reproductive organs and its contribution towards yield is indirect (Raza *et al*., 2015). The use of plant height trait to predict the yield improvement is dependent on other morphological parameters that account the spatial variation in plant height (Machado *et al*., 2002). Harvest index may depict reproductive efficacy of a genotype under fluctuating environmental patterns and is the ratio of grain to total shoot dry matter (Porker *et al.,* 2020).

Better photosynthetic activities can improve biomass which is highly corelated to grain yield and provide basis of faster improvement in wheat yield (Martin *et al.,* 2011). Multiple studies showed improvement in wheat yield through increasing biomass and HI (Austin *et al.,* 1989; Fischer *et al.,* 1998). The relationship and association among various traits may serve to play an important role to understand the opportunity of success in a breeding program as it makes sense to select a suitable genotype with desired qualities (Ali *et al*., 2015). It also helps in indirect selection for yield. In present work, to visualize the effects of terminal water stress on the relationships among the measured traits, Days to heading (50%) did not exhibited any positive co relation with any of the traits which shows that drought forced crop to mature early which resulted in negative correlation with important yield and yield related traits (Table 5) which is in a disagreement with previously reported results of Ali *et al*. (2007) and Kabir *et al*. (2017). Aslani *et al*. (2012) and Present data was in agreement with association reported between traits by Hussain *et al*. (2014) and Chimdesa *et al*. (2014).

5. Conclusion:

It is concluded that awns play important role in final grain yield and its manipulation may prove to be positive in increasing grain number and weight which will indirectly increase grain yield.

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