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Physiological basis for yield variations in dicoccum wheat genotypes under water stress condition

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Abstract
A field experiment was conducted to study "Physiological basis for yield variations in dicoccum wheat genotypes under water stress condition" during *rabi* 2018 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The experiment was laid out in split plot design. The main plot consists of water regimes irrigated (providing irrigation during germination, tillering, flowering and grain filling stages) and creating stress (only two protective irrigations during germination and grain filling stages). Sub plot consists of 10 genotypes viz., DDK-50439, DDK-50427, DDK-50438, DDK-50044, DDK-50019, DDK-1044, DDK-50050, DDK-1029, HW-1098 and local. It was noticed from the investigation that, among the genotypes, DDK-1029 recorded higher grain yield (66.91 q ha^{-1}) followed by DDK-1044 (62.229 q ha^{-1}) as compared to other genotypes and the lowest was observed in local (44.39 q ha^{-1}). The high yielding genotypes DDK-1029 and DDK-1044 had higher photosynthetic rate (20.62 and 19.18 µmol CO_2 m^{-2} sec^{-1}), transpiration rate (5.44 and 5.26 µmol H_2O m^{-2} sec^{-1}), stomatal conductance (0.48 and 0.38 µmol m^{-2} sec^{-1}) and relative water content (84.5 and 82.21%) over other genotypes and the lowest values in these parameters were found in local. The reduction in grain yield in other genotypes was due to moisture stress where significantly reduced number of tillers, spike length and number of grains per spike. The genotypes DDK-1029 and DDK-1044 had higher grain yield in both irrigated and moisture stress conditions with minimum per cent yield reduction as compared to other genotypes. This indicates that, the genotypes DDK-1029 and DDK-1044 are to be most suited for drought tolerance.

Keywords: Dicoccum wheat, photosynthetic rate, stomatal conductance, transpiration rate, wax content, yield

Introduction

Wheat (*Triticum dicoccum* Schrank) is one of the most important cereal staple food crops in the world because of its higher protein and gluten content which makes pride place among the contributing more calories to the world's human diet than any other cereals. Out of world's total area, wheat occupies 220.4 m ha^{-1} with the production of 752 m t (Anon, 2017) [2]. India is the second largest producer of wheat in the world after China and the crop has provided the widest step of growth to the Indian agriculture. Karnataka state is frontline state in South India covering 1.70 lakh ha with production of 1.71 l lakh tonnes. As main staple food, wheat continues to assume greater importance both from the point of grain productivity and quality and to provide the growing population with required quantity and quality grains is an ongoing challenge for researchers.

Among three cultivated wheat species, *Triticum dicoccum* is most important as it is suited well to high temperature stress and rust disease resistance than other two *Triticum* species. In inter specific hybridization, the desirable characters of dicoccum wheat have been successfully used to improve *aestivum* and *durum* wheat. *Triticum dicoccum* is also known as emmer wheat and in South India it is named by several names viz. *Khapli*, *Samba*, *Jave* etc. (Tandon and Hanchinal, 1992) [19] and it is mainly used for preparation of semolina, vermicelli and pasta.

In most of the wheat growing areas, it is mainly grown under rainfed conditions where, soil moisture from the previous monsoon rains is the main source of water for crop development. However, late sown wheat crop experiences higher temperature during grain filling stages leading to reduction in yield potential. Wheat breeding programmes so far have been based on the selection for yield by itself rather than physiological traits. Hence, there is a need to screen large number of suitable genotypes on the basis of physiological traits more likely to be encountered in the field rather than under ideal conditions.

Moisture stress is the complex interaction between grain yield and water availability and wheat crop at certain phases of development is more susceptible to water deficit and this water deficit causes almost all growth processes. Water stress occurring at pre-flowering, post flowering and grain filling stages decreases yield by reducing number of grains and number of spikes (Nimbalkar *et al.* 2018) [11]. Hence, there is a need to screen desirable genotypes for their tolerance to moisture stress condition in terms of physiological processes and adaptations so as to generate basic information which could be further useful in breeding programme keeping these in view, the present investigation was taken to study the physiological basis for yield variation in dicoccum wheat genotypes.

Material and methods

Field experiment was conducted during *rabi* 2018 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to study the physiological basis for yield variation in dicoccum wheat genotypes under moisture stress condition. The experiment consists of 10 genotypes namely DDK-50439, DDK-50427, DDK-50438, DDK-50044, DDK-50019, DDK-1044, DDK-50050, DDK-1029, HW-1098 and Local. The experimental design adapted in the study was split plot design with main plot as Complete irrigation (M_1) providing irrigation during germination, tillering, flowering and grain filling stages and as Moisture stress condition (M_2) – only two irrigations were given during germination and grain filling stages. The sub plot includes all the ten genotypes as mentioned earlier.

The observations on morpho-physiological parameters like plant height, number of tillers per hill, days to 50 per cent anthesis, days to maturity, yield and yield components were recorded by following standard procedures. Leaf area index (LAI) and crop growth rate (CGR) were calculated by using formula of Watson (1952) [20]. Whereas, Leaf area duration (LAD) and Specific leaf weight (SLW) were determined by using formula of Power *et. al* (1967) [13] and Yoshida *et al.* (1972) [22] respectively. Determination of relative water content (RWC) was done as per the procedure given by Barrs and Weatherly (1962) [3]. While, the physiological parameters like photosynthetic rate, stomatal conductance and transpiration rate were measured by using IRGA (Infra-red gas analyser). The estimation of epicuticular wax was done by procedure as outlined by Ebercon *et al.* (1977) [5].

Results and discussion

Morphological characters like plant height, number of tillers per hill and total dry matter production (Table-1) indicated significant differences among the dicoccum wheat genotypes. Among the genotypes, the maximum plant height was recorded in DDK-50019 (100.27 cm) followed by Local (100.17 cm) and lowest was observed in HW-1098 (75.63 cm) in irrigated condition. While, in the moisture stress condition, the genotype DDK-50050, registered maximum plant height (82.90 cm) which is on par with local, DDK-50438 and DDK-50019. Whereas, genotype HW-1098 has recorded lowest plant height (56.42 cm). The variation in plant height might be due to reduction in soil moisture which might reduce the availability of nutrients to the plant and consequently reduce the plant growth development. The plants which experienced drought stress, the stem girth shrink in response to the changes in internal water status. Cell division and expansion are more sensitive to water stress which greatly suppresses cell growth due to low turgor pressure. These observations were in confirmatory with Mirbahar *et. al* (2009) [9] and they reported that reduction in plant height during stress condition might be due to adaptive mechanism for the environment characterised as drought tolerant.

The data on number of tillers (Table-1) indicated that, the genotypes differed significantly with respect to productive tillers and among the genotypes, DDK-1029 and HW-1098 had recorded maximum number of tillers both in irrigated (8.61 and 8.11 respectively) and stress condition (6.48 and 6.40 respectively). Whereas, genotypes DDK-50439 and local has registered minimum number of tillers in both the conditions. Similar results were observed by Manoj Kumar *et. al* (2018) [8] and reported significant reduction in the number of tillers in stress condition compared to irrigated condition. The increased number of tillers under stress conditions in some of the genotypes might be due to the functional activity of photosynthetic apparatus which is clear from greater number of green leaves and assimilatory surface area.

Total dry matter (TDM) accumulation was reduced under moisture stress condition and degree of reduction depends on the growth stage of the crop, intensity and duration of drought condition. The present data (Table-1) indicated that, among the genotypes, DDK-1029 registered maximum total dry matter production in both irrigated (15.78 g hill^{-1}) and stress condition (14.68 g hill^{-1}) as compared to other genotypes. The reduction in total dry matter production in stress condition might be due to lack of available moisture which affected the translocation of assimilates to the plant parts. Similar observations were noticed by Begum and Nessa (2014).

Effect of water stress had significant effect on days to 50 per cent flowering and maturity showed significant differences among the genotypes (Table-2). The earliness in the flowering might be due to sensing of water deficit signal at early stage of growth which might have advanced the flowering to escape from the drought damage at later stages of the crop. Among the water regimes irrigated condition had maximum number of days to 50 per cent flowering (64.5) than stress condition (61.5). The genotypes DDK-50427 and DDK-50438 took 61 days in irrigated while 59 days under moisture stress condition whereas, the genotypes registered maximum number of days to 50 per cent flowering in both irrigated and stress conditions. Similarly, the genotypes DDK-50427 and DDK-50438 registered less number of days to maturity (103.6 and 104.4 in irrigated and 100.6 and 100.4 in stress indication respectively) indicating that, both the genotypes matured 3 to 4 days early which could be due to reduced photosynthetic activity and decreased translocation of photosynthates to reproductive parts which affected overall development during the stress condition thereby restrict the grain filling and might cause the canopy to senesce (Rana *et al.* 2017) [14].

It is well known that, the plant infrastructure is decided by the growth parameters. The crop growth analysis technique has been adopted as one of the standard approaches in absence of sophisticated instruments to analyse yield productivity. This concept not only involves the final crop yield and its components but also probes into the physiological events that have occurred early in the growth stage causing variation in yield potential. It was observed that, the mean leaf area index (LAI) was less in moisture stress condition compared to irrigated condition (Table-3). However, among genotypes DDK-1029 registered maximum LAI at both 60 DAS and 90 DAS (4.31 and 3.88) in irrigated condition and in moisture stress condition it registered 4.10 and 3.82 at both the stages, while, minimum LAI was recorded in Local at both the stages. The similar results were reported by Mumtaz *et. al* (2012) [10] in wheat crop and opined that, the cause of reduction in leaf area index might be due to restriction in cell enlargement thereby reduction in photosynthetic surface area. The specific leaf weight (SLW) which is measure of leaf thickness and it increased with age of the crop and decreased thereafter towards maturity. The specific leaf weight was reduced in the moisture stress conditions as compared to irrigation conditions (Table-3). The data indicated that among the genotypes DDK-1029 and HW-1098 had recorded maximum SLW in both the conditions while, it was lowest in local variety. These results were in confirmating with Lopez *et. al* (1995) [7] in cotton.

Crop growth rate (CGR) was maximum under irrigated than moisture stress conditions (Table-4). The data indicated that, CGR was increased from 30 to 90 DAS in both the conditions. Among the genotypes, DDK-50439 had recoded maximum CGR at 30-60 DAS in both irrigated (0.011 g $m^{-2}day^{-1}$) and moisture stress condition (0.006 g $m^{-2}day^{-1}$) as compared to other genotypes. While, at 60-90 DAS, the genotypes DDK-1044 and DDK1029 had registered maximum CGR under irrigated (0.041 and 0.038 g $m^{-2}day^{-1}$ respectively) and moisture stress (0.038 and 0.037 g $m^{-2}day^{-1}$ respectively) as compared to other genotypes similarly, the genotypes differenced significantly with respect to leaf area duration (LAD) and among the genotypes DDK-1029 and HW-1098 recorded significantly more LAD at both the stages under irrigated and moisture stress conditions. While, less LAD was recorded in Local variety.

Under limited water condition, one of the factors for obtaining grain yield is higher photosynthetic rate and it is raw material and the energy required for growth and development. A close relationship between leaf chlorophyll content and photosynthetic rate was observed by Watanabe and Yoshida (1970) [21] who opined that, higher chlorophyll content is one of the important factors responsible for higher photosynthetic rate. During drought condition the closure of stomata which leads to decreased CO_2 intake, affecting the rate of photosynthesis and consequently reduced the growth and yield (Ahmad *et al.* 2012) [1]. Moisture stress leads to significant reduction in net photosynthetic rate because of stomatal closure and reduced transpiration which restricts the diffusion of CO_2 fixation leading to decreased $NADP^+$ regeneration during Calvin cycle, thereby reduce the photosynthetic electron transport chain, variability in net photosynthesis, stomatal conductance and transpiration rate which have been suggested as tools for comparison and evaluation of different genotypes for drought tolerance. In the present study (Table-5), the performance of dicoccum wheat genotypes significantly differed with respect to photosynthetic rate, stomatal conductance and transpiration rate at flowering stage. It was observed that, rate of photosynthesis was reduced in stress condition (16.46 µmol CO_2 m^{-2} s^{-1}) as compared to irrigated condition (19.18 µmol CO_2 m^{-2} s^{-1}). The results were in agreement with Ravichandran and Mungse (1997) [15] and reported that, the non stressed (irrigated) crop recorded higher transpiration rate than completely stressed crop. The genotypes which recorded higher values of gas exchange parameters under stress were DDK-1029, DDK-1044, DDK-50438 and HW-1098 whereas, Local, DDK-50019 and DDK-50050 recorded less values in these parameters.

Relative water content (RWC) decreased significantly under moisture stress condition as compared to irrigated condition (Table-6). Among the genotypes DDK-1029 and HW-1098 had recorded maximum RWC in irrigated condition (86.86 and 79.13% respectively) and in stress condition (80.74 and 77.53 respectively) while, it was low in Local in both irrigated (79.13%) and stress condition (62.85%). Plants exposed to drought stress significantly reduce leaf water potential, transpiration rate and RWC with increase in leaf temperature (Siddique *et al.* 2000 and Kumar and Gupta, 2012) [18, 6]. Drought tolerant genotypes maintain high water use efficiency (WUE) by reducing water loss. The data (Table-6) indicated that, among the genotypes DDK-1029 and HW-1098 recorded higher WUE in both irrigated and stressed conditions as compared to other genotypes while Local had less WUE in irrigated (3.23 µmol CO_2 m^{-2} s^{-1} / µmol H_2O m^{-2} s^{-1}) and stress condition (3.27).

Epicuticulor wax one of the adaptive characters was increased significantly in water stress condition. Deposition of wax on both the surfaces of leaf leads to reduce transpiration loss thereby, conserve the minimum available water to maintain cell turgor. The crop response to reduce the evapotranspiration appeared in the form of accumulation of epicuticulor wax and hence, biosynthesis of wax was indirectly controlled by temperature and moisture stress. Similar results were observed in the present study (Table-6) where, epicuticular wax accumulation was more under moisture stress regime as compared to irrigated condition. Among the genotypes, DDK-1029 and HW-1098 had significantly high wax content (1.44 and 1.41 mg m^{-2} respectively) in stress condition as against (0.90 and 0.89 mg m^{-2}) in irrigated condition whereas, Local variety recorded lowest wax content. The presence of more epicuticular wax content on leaf surfaces is desirable character for rainfed cultivation (Nizamuddin and Marshall, 1988) [12].

In the present study (Table-7) the grain yield and yield components like spike length and number of grains per spike were affected significantly under moisture stress as compared to irrigated conditions. Among the genotypes, DDK-1029, HW-1098 and DDK-1044 had recorded higher grain yield in both irrigated (80.43, 74.61 and 72.33 $q.ha^{-1}$ respectively) and water stress condition (53.39, 43.28 and 43.89 $q.ha^{-1}$ respectively) as compared to other genotypes while, the lowest grain yield was reduced in Local variety under both the conditions. The reduction in the yield under moisture stress might have resulted due to reduction in the production of photo assimilates (source limitation) sink power to absorb photo-assimilates and reduce the duration of grain filling. Similar results were reported by Saeidi and Abdoli (2010) [16].

Harvest index (HI) also followed the same trend like yield and yield components and drastic reduction was observed under moisture stress condition. Among the genotypes, DDK-1029 (44.82%), DDK-1044 (42.52%) and HW-1098 (41.65%) as compared to other genotypes whereas, Local recorded lowest HI (34.66%). These results were in agreement with Nimbalkar *et al.* (2018) [11] and Sharma *et al.* (2008) [17].

Table 1: Effect of moisture stress on plant height, number of tillers and total dry matter production in dicoccum wheat genotypes

Genotypes	Plant height (cm)			Number of tiller / hill			Total dry matter production (g / hill)		
	IR	MS	Mean	IR	MS	Mean	IR	MS	Mean
DDK – 50439	70.47	62.33	66.40	5.88	5.33	5.60	12.59	12.30	12.44
DDK – 50427	95.91	80.45	88.18	7.05	5.84	6.44	13.87	13.57	13.72
DDK – 50438	97.63	81.56	89.59	7.08	6.21	6.64	13.91	13.77	13.84
DDK – 50044	98.87	79.17	89.02	6.95	5.78	6.36	13.97	13.28	13.63
DDK – 50019	100.27	81.49	90.88	6.58	5.41	5.99	13.68	12.66	13.17
DDK – 1044	75.60	61.67	68.63	7.91	5.94	6.92	15.29	14.38	14.83
DDK – 50050	99.67	82.90	91.28	7.00	5.40	6.20	14.19	12.60	13.40
DDK – 1029	78.03	62.84	70.44	8.61	6.48	7.55	15.78	14.68	15.23
HW – 1098	75.63	56.42	66.02	8.11	6.40	7.26	15.66	14.11	14.88
Local	100.17	82.37	91.27	5.50	5.10	5.30	13.13	12.08	12.60
Mean	89.22	73.12	-	7.07	5.79	-	14.21	13.34	-
ANOVA		SEm ±	CD (5%)		SEm ±	CD (5%)		SEm ±	CD (5%)
M		1.07	3.52		0.09	0.35		0.11	0.32
S		0.82	2.37		0.19	0.55		0.07	0.21
M x S		1.17	3.36		0.27	0.78		0.10	0.31

IR = Irrigated
MS = Moisture Stress

Table 2: Effect of moisture stress on Days to 50% flowering and days to maturity in dicoccum wheat genotypes

Genotypes	Days to 50% flowering			Days to maturity		
	IR	MS	Mean	IR	MS	Mean
DDK – 50439	70.0	66.0	68.0	111.9	108.3	110.1
DDK – 50427	61.0	59.0	60.0	103.6	100.6	102.1
DDK – 50438	61.0	59.0	60.0	104.4	100.4	102.4
DDK – 50044	63.0	60.0	61.5	107.5	101.9	104.7
DDK – 50019	66.0	63.0	64.5	105.5	99.5	102.5
DDK – 1044	63.0	60.0	61.5	109.5	104.5	107.0
DDK – 50050	64.0	61.0	62.5	107.5	102.5	105.0
DDK – 1029	62.0	59.0	60.5	106.5	100.5	103.5
HW – 1098	62.0	59.0	60.5	109.5	105.9	107.7
Local	73.0	69.0	71.0	111.6	107.2	109.4
Mean	64.5	61.5	-	107.76	103.13	-
ANOVA		SEm ±	CD (5%)		SEm ±	CD (5%)
M		0.46	2.84		0.66	3.31
S		1.53	4.41		2.22	5.70
M x S		2.17	NS		3.14	NS

IR = Irrigated
MS = Moisture Stress

Table 3: Effect of moisture stress on Leaf area index (LAI) and specific leaf weight (SLW) in dicoccum wheat genotypes

Genotypes	LAI						SLW					
	60 DAS			90 DAS			60 DAS			90 DAS		
	IR	MS	Mean	IR	MS	Mean	IR	MS	Mean	IR	MS	Mean
DDK – 50439	2.74	2.53	2.64	2.52	2.32	2.42	1.21	1.15	1.18	0.94	0.87	0.90
DDK – 50427	3.26	3.18	3.22	3.13	2.87	3.00	1.31	1.27	1.29	0.98	0.90	0.94
DDK – 50438	3.21	3.12	3.17	3.13	2.74	2.93	1.29	1.24	1.26	0.97	0.89	0.93
DDK – 50044	3.17	3.01	3.09	2.93	2.68	2.81	1.30	1.21	1.25	0.98	0.90	0.94
DDK – 50019	2.65	2.54	2.60	2.62	2.50	2.56	1.23	1.15	1.19	0.95	0.87	0.91
DDK – 1044	3.50	3.48	3.49	3.29	3.06	3.18	1.35	1.23	1.29	0.98	0.93	0.96
DDK – 50050	2.83	2.62	2.73	2.75	2.52	2.63	1.28	1.18	1.23	0.97	0.88	0.93
DDK – 1029	4.31	3.88	4.10	3.49	3.29	3.39	1.41	1.32	1.37	0.99	0.96	0.97
HW – 1098	3.90	3.74	3.82	3.36	2.94	3.15	1.35	1.27	1.31	0.99	0.95	0.97
Local	2.61	2.41	2.51	2.33	2.01	2.17	1.14	1.01	1.07	0.93	0.84	0.88
Mean	3.22	3.05	-	2.95	2.69	-	1.29	1.20	-	0.96	0.90	-
ANOVA		SEm ±	CD (5%)		SEm ±	CD (5%)		SEm ±	CD (5%)		SEm ±	CD (5%)
M		0.02	0.15		0.02	0.14		0.01	0.07		0.004	0.027
S		0.02	0.08		0.03	0.08		0.01	0.04		0.011	0.033
M x S		0.04	0.11		0.04	0.12		0.02	NS		0.016	NS

IR = Irrigated
MS = Moisture Stress

Table 4: Effect of moisture stress on Crop growth rate (CGR) and Leaf area duration (LAD) in dicoccum wheat genotypes

Genotypes	CGR ($g.m^{-2}day^{-1}$)						LAD (Days)					
	30-60 DAS			60-90 DAS			30-60 DAS			60-90 DAS		
	IR	MS	Mean	IR	MS	Mean	IR	MS	Mean	IR	MS	Mean
DDK – 50439	0.011	0.006	0.009	0.033	0.031	0.032	15.02	13.43	14.22	16.97	14.68	15.83
DDK – 50427	0.007	0.005	0.006	0.037	0.034	0.035	22.42	20.70	21.56	22.93	20.23	21.58
DDK – 50438	0.008	0.005	0.006	0.034	0.033	0.034	21.30	20.06	20.68	22.14	19.65	20.89
DDK – 50044	0.006	0.003	0.004	0.036	0.031	0.034	20.27	18.19	19.23	21.30	18.30	19.80
DDK – 50019	0.008	0.003	0.006	0.034	0.031	0.032	16.26	14.86	15.56	17.97	15.61	16.79
DDK – 1044	0.005	0.002	0.004	0.041	0.038	0.039	23.61	22.21	22.91	24.26	22.51	23.38
DDK – 50050	0.006	0.003	0.004	0.036	0.036	0.036	17.58	15.86	16.72	19.70	16.21	17.96
DDK – 1029	0.005	0.002	0.004	0.038	0.037	0.038	27.97	25.55	26.76	28.66	25.24	26.95
HW – 1098	0.004	0.002	0.003	0.034	0.034	0.034	26.11	23.91	25.01	26.52	22.79	24.65
Local	0.008	0.005	0.007	0.034	0.031	0.032	14.92	13.04	13.98	16.96	14.02	15.79
Mean	0.007	0.004	-	0.036	0.034	-	20.54	18.78	-	21.74	18.98	-
ANOVA		SEm ±	CD (5%)		SEm ±	CD (5%)		SEm ±	CD (5%)		SEm ±	CD (5%)
M		0.0005	0.0029		0.0003	0.0021		0.16	0.98		0.22	1.36
S		0.0005	0.0015		0.0006	0.0018		0.32	0.94		0.21	0.60
M x S		0.0008	NS		0.0009	NS		0.46	NS		0.29	0.85

IR = Irrigated
MS = Moisture Stress

Table 5: Effect of moisture stress on Photosynthetic rate, Transpiration rate and stomatal conductance at flowering stage in dicoccum wheat genotypes

Genotypes	Photosynthetic rate ($\mu mol\ CO_2\ m^{-2}\ s^{-1}$)			Transpiration rate ($\mu mol\ H_2O\ m^{-2}\ s^{-1}$)			Stomatal conductance ($\mu mol\ m^{-2}\ s^{-1}$)		
	IR	MS	Mean	IR	MS	Mean	IR	MS	Mean
DDK – 50439	17.46	15.38	16.42	5.33	4.33	4.83	0.25	0.22	0.23
DDK – 50427	19.95	17.13	18.54	5.62	5.05	5.34	0.32	0.29	0.30
DDK – 50438	19.37	16.81	18.09	5.49	5.04	5.27	0.30	0.28	0.29
DDK – 50044	18.71	16.02	17.36	5.48	4.95	5.21	0.28	0.25	0.26
DDK – 50019	17.52	15.13	16.33	5.36	4.65	5.01	0.24	0.21	0.23
DDK – 1044	20.23	18.12	19.18	5.78	5.12	5.45	0.40	0.36	0.38
DDK – 50050	18.42	15.52	16.97	5.37	4.60	4.98	0.26	0.23	0.25
DDK – 1029	21.55	19.68	20.62	5.96	4.91	5.44	0.50	0.46	0.48
HW – 1098	21.13	16.49	18.81	5.74	4.78	5.26	0.46	0.38	0.42
Local	17.50	14.34	15.92	4.96	3.63	4.30	0.20	0.18	0.19
Mean	19.18	16.46	-	5.51	4.71	-	0.32	0.29	-
ANOVA		SEm ±	CD (5%)		SEm ±	CD (5%)		SEm ±	CD (5%)
M		0.18	1.11		0.04	0.13		0.005	0.019
S		0.26	0.75		0.09	0.26		0.005	0.015
M x S		0.37	1.07		0.13	0.38		0.007	0.021

IR = Irrigated
MS = Moisture Stress

Table 6: Effect of moisture stress on relative water content (RWC), Wax content and water use efficiency (WUE) at flowering stages in dicoccum wheat genotypes

Genotypes	RWC (%)			Wax content ($mg\ cm^{-2}$)			WUE ($\mu mol\ CO_2\ m^{-2}\ s^{-1}$ / $\mu mol\ H_2O\ m^{-2}\ s^{-1}$)		
	IR	MS	Mean	IR	MS	Mean	IR	MS	Mean
DDK – 50439	80.62	63.49	72.06	0.76	1.40	1.08	3.24	3.46	3.35
DDK – 50427	82.88	76.34	79.61	0.88	1.40	1.14	3.32	3.65	3.49
DDK – 50438	83.21	75.41	79.31	0.86	1.39	1.12	3.29	3.53	3.41
DDK – 50044	81.62	72.05	76.84	0.84	1.38	1.11	3.35	3.31	3.33
DDK – 50019	79.87	66.29	73.08	0.79	1.34	1.07	3.21	3.33	3.27
DDK – 1044	85.86	78.57	82.21	0.88	1.42	1.15	3.40	3.95	3.68
DDK – 50050	80.12	68.63	74.37	0.82	1.37	1.09	3.37	3.44	3.41
DDK – 1029	88.28	80.74	84.51	0.90	1.44	1.17	3.55	3.01	3.78
HW – 1098	86.86	77.53	82.19	0.89	1.41	1.15	3.54	3.46	3.50
Local	79.13	62.85	70.99	0.75	1.30	1.03	3.23	3.27	3.30
Mean	82.85	72.19	-	0.84	1.39	-	3.35	3.55	-
ANOVA		SEm ±	CD (5%)		SEm ±	CD (5%)		SEm ±	CD (5%)
M		1.00	3.12		0.012	0.073		0.032	0.196
S		0.62	1.79		0.008	0.022		0.063	0.181
M x S		0.88	2.53		0.011	0.031		0.089	0.256

IR = Irrigated
MS = Moisture Stress

Table 7: Effect of moisture stress on yield, yield components and Harvest index (HI) in dicoccum wheat genotypes

Genotypes	Spike length (cm)			No. of grains / spike			Grain yield (q./ha.)			Harvest Index (HI)		
	IR	MS	Mean	IR	MS	Mean	IR	MS	Mean	IR	MS	Mean
DDK – 50439	7.1	6.5	6.8	31.5	23.3	27.4	55.56	41.22	48.39	36.72	32.86	34.79
DDK – 50427	7.3	7.0	7.2	33.1	26.4	29.8	69.89	46.72	58.31	43.24	39.35	41.29
DDK – 50438	7.4	6.9	7.1	32.9	25.4	29.2	69.89	44.72	57.31	42.20	38.84	40.52
DDK – 50044	7.2	6.5	6.9	32.7	25.3	29.0	65.56	45.11	55.33	41.46	38.45	39.95
DDK – 50019	7.2	6.6	6.9	30.0	25.6	27.8	58.28	42.00	50.14	37.48	34.15	35.81
DDK – 1044	8.3	7.8	8.0	36.7	29.3	33.0	72.33	52.11	62.22	44.43	40.62	42.52
DDK – 50050	7.2	6.6	6.9	31.6	25.0	28.3	63.00	43.89	53.45	38.72	36.23	37.48
DDK – 1029	8.4	8.1	8.3	38.5	32.0	35.2	80.43	53.39	66.91	46.08	43.57	44.82
HW – 1098	8.2	7.1	7.7	37.6	28.7	33.1	74.61	43.28	58.94	44.80	38.49	41.65
Local	7.1	6.2	6.6	30.7	24.7	27.7	52.56	36.22	44.39	37.64	31.68	34.66
Mean	7.5	6.9	-	33.5	26.6	-	66.21	44.87	-	41.28	37.42	-
ANOVA		SEm ±	CD (5%)		SEm ±	CD (5%)		SEm ±	CD (5%)		SEm ±	CD (5%)
M		0.067	0.193		0.31	1.08		1.52	3.25		0.56	1.45
S		0.080	0.230		0.41	1.18		1.39	4.00		0.41	1.18
M x S		0.113	0.325		0.58	1.68		1.97	5.66		0.58	1.67

IR = Irrigated
MS = Moisture Stress

Conclusion: among the genotypes, DDK-1029 recorded higher grain yield (66.91 q ha^{-1}) followed by DDK-1044 (62.229 q ha^{-1}) as compared to other genotypes and the lowest was observed in local (44.39 q ha^{-1}). The high yielding genotypes DDK-1029 and DDK-1044 had higher photosynthetic rate (20.62 and 19.18 µmol CO_2 m^{-2} sec^{-1}), transpiration rate (5.44 and 5.26 µmol H_2O m^{-2} sec^{-1}), stomatal conductance (0.48 and 0.38 µmol m^{-2} sec^{-1}) and relative water content (84.5 and 82.21%) over other genotypes and the lowest values in these parameters were found in local

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