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Identification of physiological and yield related traits of wheat (*Triticum aestivum* L.) under varying soil moisture stress

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ABSTRACT

An experiment was conducted during two *rabi* seasons of 2008-09 and 2009-10 on wheat to find suitable physiological traits in wheat genotypes for restricted irrigation application in concrete drought plots. The experiment was designed as split plot consisting of three irrigation schedules viz., normal irrigated (control), two irrigations at 25 and 105 DAS (moderate stress) and single irrigation at 25 DAS (rainfed) in the main plots and four genotypes namely WH 1025, WH 1080, WH 1081 and C 306 in the sub-plots with three replications. The moisture stress created by restricting the irrigation decreased the leaf water potential (LWP), canopy temperature depression (CTD), transpiration rate, stomatal conductance and photosynthesis. Moisture stress decreased the yield and yield attributes with maximum reduction in number of tillers per plant followed plant height and ear length. Among the genotypes, WH 1080 produced significantly higher yield due to higher test weight, plant water status and higher rate of photosynthesis of flag leaf during anthesis compared to other genotypes under rainfed condition.

Key words: Leaf water potential, moisture stress, photosynthesis, relative water content, wheat.

In India, although 80% of the wheat is grown under irrigated conditions, only one-third receives full irrigation while the remainder is cultivated under partial irrigation with 1-2 irrigations over the cropping season. It is likely that water will become a limiting factor for sustained production of wheat in India (Joshi *et al*., 2007). Wheat crop exposed to water stress particularly during grain growth period coincides with high temperature and reduced water supply for irrigation. It was found that yield, kernels per spike, biomass and plant height were more drought sensitive compared with spike number and thousand kernel weight. Some morphological and physiological traits contribute to grain yield greatly. Morphological traits such as number of tillers, grain number per spike, fertile tillers number per plant, thousand grain weight, peduncle length, awn length, plant height, spike length, kernel number per spike, grain weight per spike, etc. affect the wheat tolerance to the moisture shortage in the soil (Aminzadeh, 2010; Sharma and Kumar, 2010). Water loss can lower leaf water potentials, leading to reduced turgor, stomatal conductance and photosynthesis, and ultimately, the reduced growth and yields. Several physiological traits, such as canopy temperature depression (CTD), membrane thermo-stability, leaf stomata conductance and photosynthetic rate at anthesis stage, which can contribute to continued growth under water stress, have been identified (Sayar *et al.,* 2005; Chena *et at.,* 2012).

Therefore, drought tolerance in wheat has been a major aim of many breeding programs both nationally and internationally in order to improve crop productivity under water-limiting conditions. Selection of suitable crop and their varieties is one of the ways for achieving higher yield and water use efficiency. The ideal genotype for moisture stress condition must combine a reasonably high yield potential under varied environmental conditions with specific plant characters which could buffer yield against severe moisture stress and heat stress (Richards *et al*., 2010). Hence the present experiment was conducted to find out the genotypes of wheat on the basis of suitable agro-physiological traits for moisture stress condition.

MATERIALS AND METHODS

An experiment was conducted on bread wheat (*Triticum aestivum* L) during two consecutive *rabi* seasons of 2008-09 and 2009-10 in concrete drought plots (30 m length x 6 m width x 2 m depth) at Crop Physiology Field Laboratory of Agronomy Research Farm, CCS Haryana

Agricultural University, Hisar (29°-10'N latitude, 75°-46' E longitude and 215 m altitude), India. The treatments consisted of three moisture stress levels viz., normal irrigated (control) i.e. five irrigations at 25, 45, 85, 105 and 120 DAS; moderate stress level by withholding irrigations (two irrigations at 45 and 105 DAS) and rainfed (one irrigation at 25 DAS during 2008-09 only) and four genotypes namely WH 1025, WH 1080, WH 1081 and C 306. Ten rows of 2.5 m length with row to row spacing of 22.5 cm of each genotype were sown. The available soil moisture at sowing was 15.2 % soil moisture (v/v basis) in 150 cm soil profile. The experiment was laid out in split plot design keeping irrigations in main plot and genotypes in sub plots with three replications. The crop was sown in the first week of November in both years. The soil of the drought plots was light textured dunal sand with low in organic carbon (0.08 %), alkaline in reaction (pH 8.1) and low in fertility (available N 65.2 kg ha^{-1}, available P_2O_5 8.5 kg ha^{-1} and available K_2O 160 kg ha^{-1}). All other agronomical practices were followed as per recommended package of practices. The rainfall received during the crop season was 48.2 mm and 90.9 mm during 2008-09 and 2009-10, respectively. Soil moisture content (by Neutron Moisture Meter, Troxler, USA) was recorded on the day of physiological measurement at anthesis stage. On the average, the values of soil moisture content were 13.07 ± 0.26 % (v/v, mean ±SD) in normal irrigated, 9.26± 0.20 % in moderate stress and 5.13 ± 0.51 % in rainfed environment

The plant water relation parameters were recorded at anthesis stage (90 – 95 DAS) between 1000 to 1100 h. A fully expanded flag leaf from the top of the plant on the main shoot was used for the measurements. The leaf water potential (LWP) was measured by Pressure Chamber (PMS Instrument Co., Oregon, USA), relative water content (RWC) was estimated with the formula given by Kumar and Elston (1992). Transpirational cooling *i.e.* canopy temperature depression (CTD) was measured by using Infra-red thermometer (Model AG-42 Tele-temp Corp.CA) between 1300 to 1400 h. The photosynthetic rate (P_N) was measured on flag leaf using Infra-red Gas Analyzer (IRGA, CIRAS-1, PP Systems, UK.). The measurements were made on the portion of leaves exposed directly to sunlight on five plants in random in each plot. Data presented are mean of four sets of measurements. At the same time, stomatal conductance (GS) and transpiration (E) were also determined with IRGA. The yield attributes were recorded on sample of five plants from each plot. Grain yield was recorded from the individual plot and expressed in kilogram per hectare. The results of experiment were similar during both the years; hence, the data was pooled and data were subjected to analysis of variance using online Statistical Analysis Package (OPSTAT, Computer Section, CCS Haryana Agricultural University, Hisar, India) and mean separated by Duncan's Multiple Range Test at $P<0.01$. Correlation and regression were also calculated.

RESULTS AND DISCUSSION

The physiological breeding approach aim to combine the traits in identifying superior genotypes and our data demonstrate that several of the traits we examined show good promise as potential selection criteria for improving drought tolerance in wheat. The increased level of moisture stress decreased the plant water relation traits i.e. CTD, LWP and RWC (Fig. 1). The percent decrease in CTD was highest followed LWP and RWC which was 83.5, 44.3 and 8.7 percent in rainfed and 62.3, 16.5 and 4.9 percent in moderate stress, respectively. There was large genotypic variation for physiological traits, during the two growing seasons, which implies that there is a great opportunity to exploit these traits for crop improvement. Among the genotypes the highest LWP and RWC were observed in WH 1080 closely followed by WH 1081 which were statistically at par. The CTD did not differ significantly among the genotypes themselves. The interaction of moisture stress level with genotypes was significant in all the three plant water relation parameters. The relative reduction in LWP with increased moisture stress from moderate to severe was minimum in WH 1025 although highest value of LWP under severely stressed treatment was in WH 1080. Almost similar trend was observed in RWC and CTD in other genotypes under severely stressed environment. Praba *et al.* (2009) have also reported the decrease in plant water status under drought situation. The gaseous exchange traits like photosynthesis, stomatal conductance and transpiration also decreased with increase in water stress levels (Fig. 2). The per cent decrease in GS, P_N and E under moderate stress over normal irrigated control was 36.4, 33.0 and 15.6 percent, respectively. Whereas, in the corresponding decrease in the above physiological traits was 62.9, 55.5 and 49.6 percent, respectively under rainfed condition. Enhanced RWC helped the plants to perform the physiological processes like stomatal conductance, photosynthesis, transpiration and biochemical metabolism

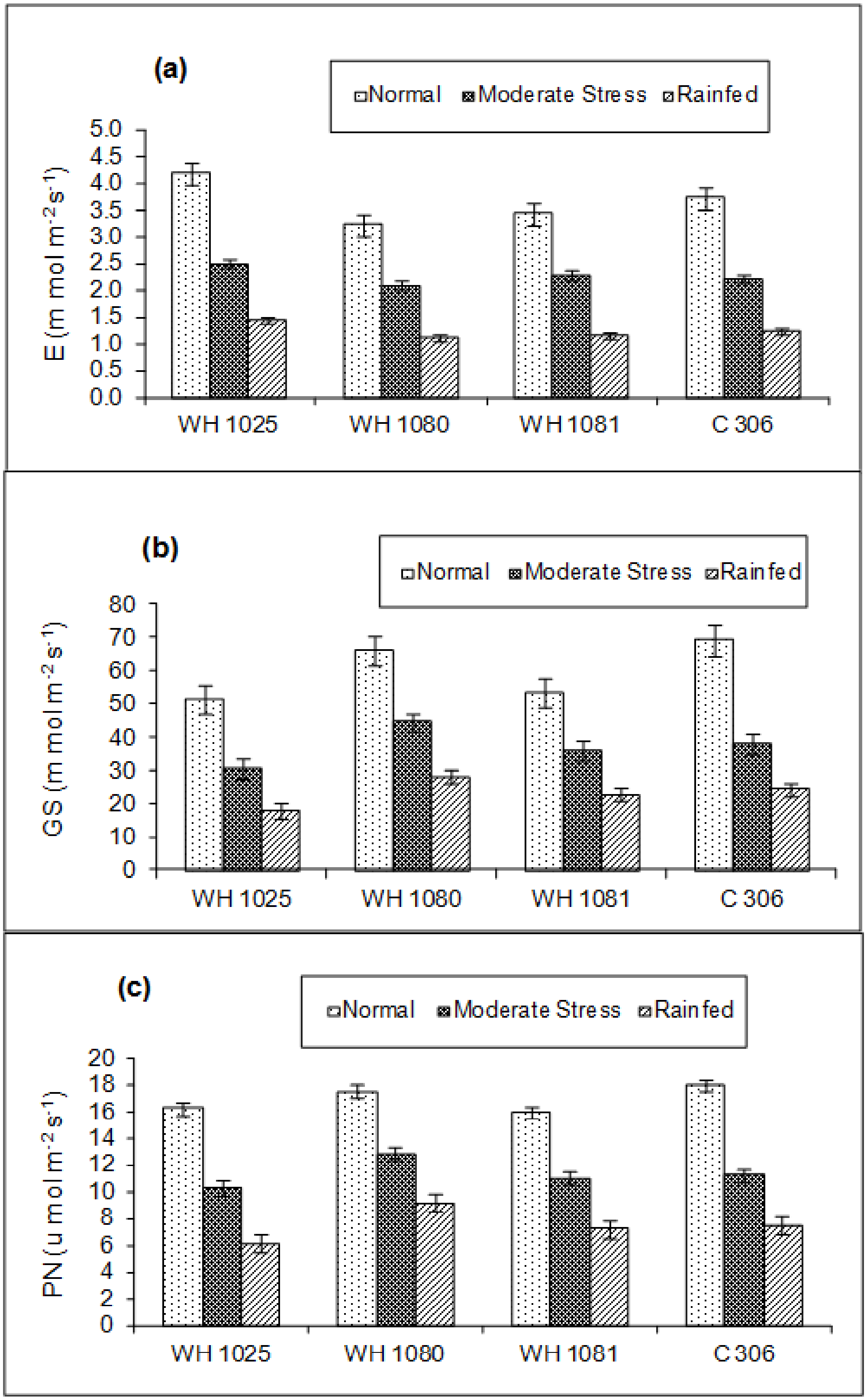

Fig. 2: Effect of soil moisture deficit on (a) transpiration rate, (b) stomatal conductance and (c) photosynthetic rate of wheat genotypes

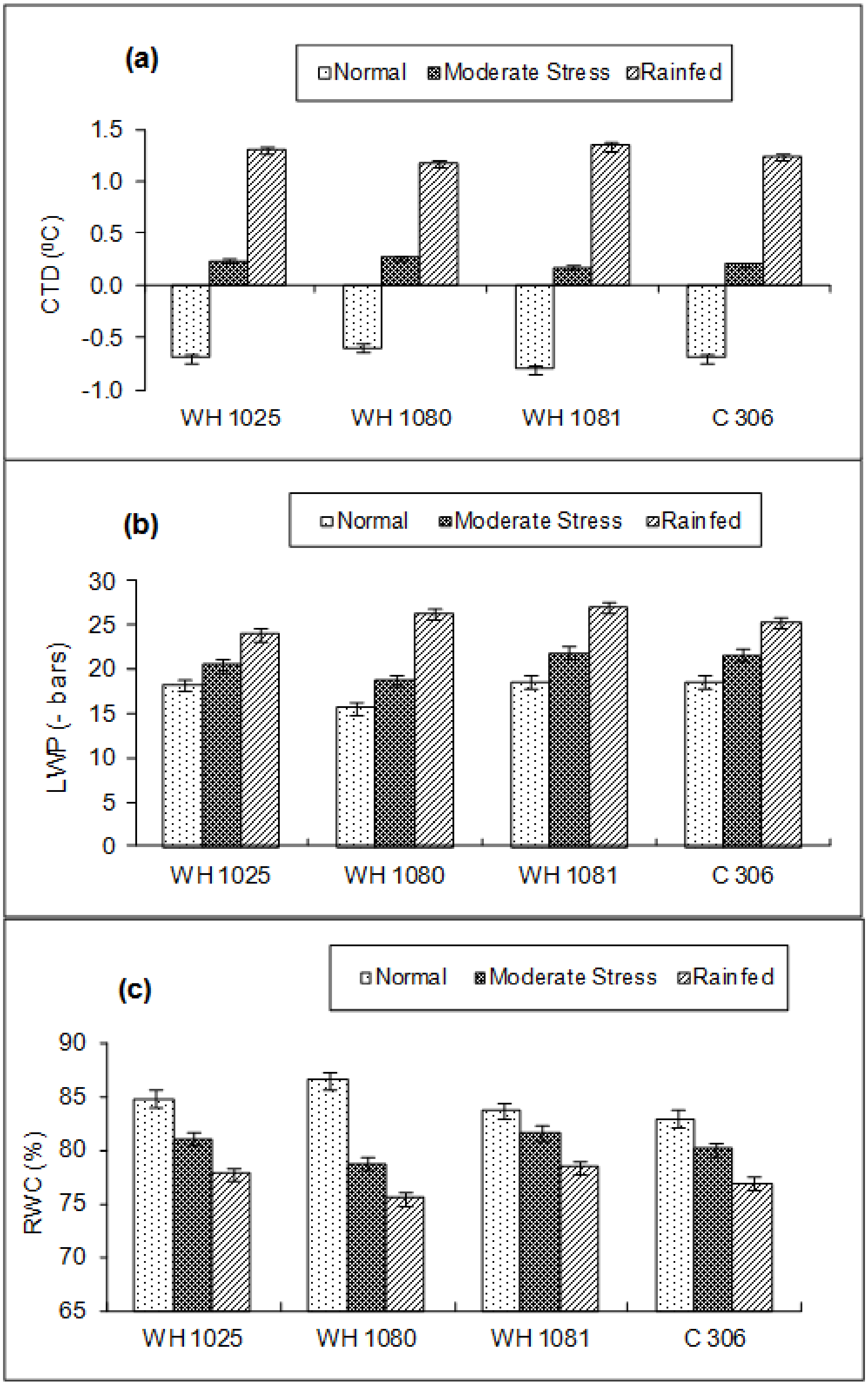

Fig. 1: Effect of soil moisture deficit on (a) canopy temperature depression, (b) leaf water potential, (c) relative water content of wheat genotypes

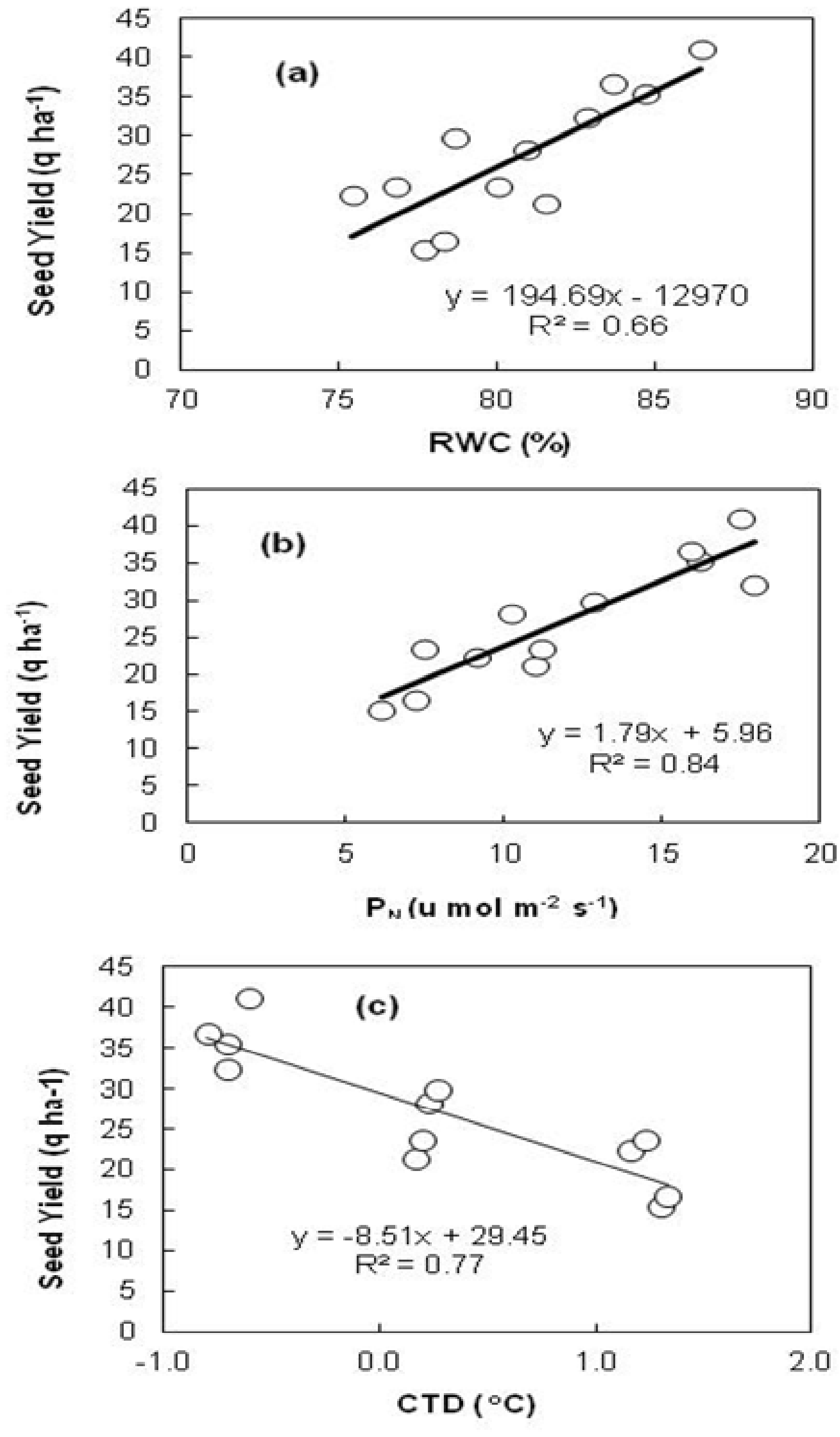

Fig. 3: Relationship between seed yield and (a) relative water content (b) photosynthetic rates, (c) canopy temperature depression. RWC, CTD and P_N recorded at anthesis stage and seed yield recorded at harvest were used for establishing the relationships.

Table 1:. Effect of soil moisture deficit on yield attributes and yield of wheat genotypes.

Treatments	Plant height (cm)	Number of tillers m^{-2}	Spike length (cm)	Test weight (g)	Grain yield (kg h^{-1})	Biological yield (kg h^{-1})	Harvest Index (%)
Irrigation schedule							
Normal irrigated	93.3	117.0	9.2	33.7	3645	10634	34.3
Moderate stress	89.3	99.5	8.7	29.2	2753	9214	29.9
Rainfed	79.3	88.8	8.2	31.2	2003	7029	28.5
CD at 5 % (p=0.05)	4.2	8.6	0.4	2.0	302	924	1.6
Genotypes							
WH 1025	78.7	93.0	9.3	28.3	2642	8499	31.1
WH 1080	82.0	109.3	8.7	35.2	3119	9011	34.6
WH 1081	83.0	104.3	8.5	32.1	2959	8522	34.7
C 306	105.4	100.3	8.2	35.1	2549	9804	26.0
CD at 5 % (p=0.05)	3.8	3.1	NS	1.3	186	446	2.3

to continue more efficiently even under low soil moisture condition (Chena *et al.* 2012). Among the genotypes the highest P_N was observed in WH 1080 closely followed by WH 1081 and C 306. Cooler canopy of these genotypes might be associated with better water uptake/ efficient root and water status for longer period, resulting in stomata being open and transpiration to continue even during moisture stress (Ferrantea *et al.* 2012 and Wasson *et al.* 2012). Genotypes which maintained higher RWC had cooler canopy (higher CTD), higher rates of P_N and vice versa. However, LWP was not correlation with traits of economic interest whereas RWC and CTD were positively correlated with biomass and seed yield (Fig. 3). Genotypes displaying higher RWC produced more number of grains/spike, higher biomass and seed yield. There was a strong and positive correlation between RWC and P_N indicating that genotypes showing high RWC displayed higher rates of photosynthesis.

The phenological behavior and duration of crop growth was similar in all the tested genotypes under different soil moisture conditions (data not reported). Grain yield and its attributes were reduced significantly due to moisture stress (Table 1). The percent reduction in grain yield was 24.5 and 45.0 over control in moderately and severely stressed environment, respectively. These variations were due to similar reductions in yield attributes *i.e.* number of productive tillers per m^2 (15.0 and 24.1 %) and spike length (6.2 and 11.4 %) under moderate and rainfed, respectively. The significant higher grain yield was recorded in WH 1080 and WH 1081 under the three environments. The higher grain yield in WH 1080 was because of higher number of effective tillers per m^2, harvest index and test weight. Further it was also due to its higher plant water potential (LWP), maintaining cooler canopy (CTD) and higher relative water content than other genotypes. Genotype WH 1080 possessed significantly higher rate of photosynthesis and stomatal conductance over other tested genotypes. The seed yield had highly significant association with RWC, $P_{N,}$ and CTD (Fig. 3). This showed that plant water relation parameters had direct bearing on yield formation via yield attributes. The better plant water status observed in WH 1080 has helped in higher rate of stomatal conductance which finally gave better opportunity for CO_2 fixation through photosynthesis. These results confirm the earlier findings of Sharma and Kumar (2010).

Hence on the basis of these two years results it may be concluded that the plant water relation parameters had direct bearing on yield formation via yield attributes. Therefore, the measurement of RWC, LWP and CTD during midday hours which is simple and rapid could be exploited in wheat improvement programmes for drought tolerance. The genotypes WH 1080 and WH 1081 with higher potential yield along with better plant water status and gaseous exchange under different moisture stress levels should be grown for higher production and economic return.

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