Biological Forum – An International Journal **13(3): 58-63(2021)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Effect of Drought Stress on Grain Quality Attributes in Wheat (*Triticum aestivum L.*) Varieties

***Dommalapati Sudhakara Rao*[1*]*, Midathala Raghavendra*[2]*, Parveen Gill*[3]*, Shashi Madan*[4]* and Renu Munjal*[5]**

[1]*Associate Professor, Department of Biochemistry, Agricultural College, Rajamahendravaram-533 103, Acharya N. G. Ranga Agricultural University, (Andhra Pradesh), India.*
[2]*Assistant Controller of Examinations, Administrative Building Acharya N. G. Ranga Agricultural University, Guntur, (Andhra Pradesh), India.*
[3]*Assistant Project Officer, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, (Haryana), India.*
[4]*Retd. Professor of Biochemistry, Sector-14, Hisar, (Haryana), India.*
[5]*Professor & Head, Department of Crop Physiology, CCS Haryana Agricultural University, (Haryana), India.*

(Corresponding author: Dommalapati Sudhakara Rao)*
(Received 12 May 2021, Accepted 15 July, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Drought stress severely limits wheat crop production and adversely affects grain quality. The effect is more severe when the grain filling stage of crop coincidence with drought. The nutritional complement of stressed grains is significantly decreased which will contribute to malnutrition to the consumers whose staple food is wheat. The present study aims to evaluate some quality attributes to assess the extent of effect caused in wheat grains and the data obtained would be used for the development of better drought-tolerant wheat varieties. Two wheat varieties *viz.* WH 1105 and WH 1025 were grown in the field under drought stress and irrigated conditions, grains were selected after harvest of the crop and evaluated for quality traits. Some quality attributes such as grain appearance score, hectoliter weight, grain hardness, crude protein content, wet and dry gluten were evaluated in two wheat varieties *viz.* WH 1105 and WH 1025. Grain appearance score of 5.9 was observed in WH 1105 in both irrigated and drought conditions while in WH 1025 the score was decreased from 6.1 to 5.9 under drought compared to irrigated conditions. Hectolitre weight and grain hardness were decreased in both wheat varieties under drought conditions. The crude protein content was increased with a percent increase of 5.97 and 1.56 in WH 1105 and WH 1025 respectively under drought conditions. Wet and dry gluten showed consistent enhancements under drought, however, the percent increase was lower in WH 1025 than WH 1105. These results suggest that the quality of wheat grains was affected under drought stress conditions.

Keywords: Wheat (*Triticum aestivum L.*), drought stress, grain quality attributes, grain appearance score, hectolitre weight, grain hardness, crude protein content, wet gluten and dry gluten.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the major food crops in India that is severely affected by environmental factors due to changing precipitation patterns caused by climate change. Among the cereals, it stands second in terms of production and acreage and serving nutritional requirements to the majority of the population across the globe (Mehmet *et al.*, 2018). Wheat is a key staple crop for global food security, providing about 20 percent of the total dietary calories and protein (Ninai *et al.*, 2019). The combination of high temperature and water deficit is common in dry and semi-dry regions worldwide and claims extensive yield losses (Yashavanthakumar *et al.*, 2021). Drought stress reduced yields of spring wheat more than winter wheat (Jian *et al.*, 2017). Severe droughts are expected in near future in arid and semi-arid zones due to the rise in global temperature (Imran *et al.*, 2020). Drought stress at the grain filling stage not only limits crop yields but also grain quality. Grain quality is expressed through a complex of indices including its physical condition, chemical composition, and biochemical characteristics (Ivanova *et al.*, 2013). Among grain quality traits, grain hardness, flour color, polyphenol oxidase, protein content, protein quality, and starch pasting properties have been shown to affect the quality attributes of wheat (Liu *et al.,* 2003). Drought stress significantly affects common wheat yield and quality, especially the composition of seed storage proteins that form during the grain filling stage (Ozturk & Aydin, 2004). Under drought stress, the protein content, SDS-sedimentation value, and wet gluten of winter wheat have been demonstrated to increase from germination to maturation. Drought stress at the grain filling period dramatically reduces grain yield (Nezar, 2005; Farzad *et al.,* 2012). Wheat grain yield and yield components such as productive tillers, grains per spike, kernel weight, biological yield, and harvest index are adversely affected by soil moisture stress (Ghulam *et al.,* 2011; Hafiz *et al.,* 2012). The overall moisture deficit-induced reduction in yield was primarily due to a reduction in kernel weight and the number of kernels per spike (Benjamin & Nielsen, 2006; Prabha *et al.,* 2009). Hui *et al.,* (2007) had reported that grain filling rate increased slightly initially, but decreased significantly during late grain filling under high temperature indicating the alterations to various phenological parameters influenced by stress. In spite of several reports on the effect of drought stress on quality attributes in wheat, work on WH 1105 and WH 1025 wheat varieties is limited. Therefore, in the present investigation, two wheat varieties were selected for studying grain quality parameters affected by drought stress.

MATERIALS AND METHODS

Seeds of two varieties of wheat *viz.* WH1105 (Drought sensitive) and WH 1025 (Drought tolerant) were obtained from the Wheat and Barley Section, Department of Genetics and Plant Breeding, College of Agriculture, CCSHAU, Hisar. Seeds were sown in micro plots on the university farm. Drought stress was created by giving pre-sown irrigation only for the micro plots designated for this purpose. Normal agronomical recommended irrigations were given for other micro plots. Wheat grains were selected after the harvest of the crop for quality assessments.

A. Quality parameters

Grain appearance. Grain samples were initially taken into clean Petri plates, arranged in an array of rows on clean filter paper laid on the laboratory workbench, expert of wheat evaluated the series of samples by visual observation considering grain size, shape, soundness, color, and luster then scores were awarded to each sample on a 10-point scale. The scores so obtained were recorded.

Hectolitre weight. Hectolitre weight was estimated by the method of Marshall *et al.,* (1986), where samples of grains were filled in iron made a medium-sized cylinder of hectolitre weight instrument and closed the slider a top to shutdown it to ensure that the taken volumes of seeds were intact in a cylinder. Then the slider was opened in a funnel of the instrument to make sure that they fell in a beaker and the weight of the grains was recorded on electronic weighing balance.

Grain hardness. Grain hardness was determined by the method of Richard *et al.,* (2008), where it was measured by pressing ten average-sized well-fitted grains in grain hardness tester-189, HICON E 2086 (Manufactured by Kiya Seisakusho Ltd., Japan). The force was applied to crush the grains with a hand where there was a concomitant turning of the indicator needle on its scale which corresponds to the force applied. The force (kg) displayed on dial per grain at the time of crushing was recorded.

Crude protein content was estimated by the micro-Kjeldahl method (AOAC, 2000).

B. Procedure

Digestion. A sample of 0.2 g was taken in the micro-Kjeldahl flask. 10 ml of conc. H_2SO_4 and 2 g digestion mixture (K_2SO_4 and $CuSO_4$ at 9:1 ratio) was added to it. The flasks were placed on a digestion bench and heated till the solution became clear blue. The flasks were removed, cooled, and volume was made to 100 ml with distilled water.

Distillation. An aliquot of 10 ml was transferred to micro-Kjeldahl assembly and 10 ml of 40 percent NaOH was added to it. 10 ml of N/100 H_2SO_4 was taken in a conical flask to that 2-3 drops of methyl red indicator were added. This conical flask was set under a condenser. The distillation was carried for 10-15 min. till the solution turned blue.

Titration. The conical flask was removed after washing the tip of the condenser with distilled water into the flask. The content of the flask was titrated against N/100 NaOH till the endpoint reached (red to pink). The volume of alkali used for neutralization of H_2SO_4 was recorded. The amount of nitrogen and hence protein in the sample was calculated using the following relationship:

1 ml N/100 H_2SO_4 = 0.00014 g N

Where,

V=Volume of N/100 H_2SO_4 taken - Volume of N/100 NaOH used for titration

D= Dilution factor (Volume made in volumetric flask)

W= Weight (g) of the sample

A= Aliquot taken for distillation

Estimation of wet and dry gluten. Wet and dry gluten was estimated by employing the standard method of analysis (AOAC, 2000) where the sample material of 10 g wheat grain flour was transferred to a beaker, to that 7 ml of water was added; the contents were mixed with the help of a glass rod and made into a small ball of dough. Immersed dough ball into a beaker containing 50 ml of water, allowed for 30 min. and washed with hands under running tap water until free from starch. To check the presence of starch if any, KI was added to the last extract and the absence of violet color indicated complete removal of starch. Squeezed out the adhered water from the extracted gluten and weighed which represented the wet gluten which was later kept in a hot air oven at 105^{o}C for 6 hours and weighed again which represented the dry gluten. The amounts of wet and dry gluten were calculated from the following formula:

W_1 = Weight of sample taken

W_2 = Weight of moist gluten

W_3 = Weight of

RESULTS

A. Effect of drought stress on quality parameters

Grain appearance score. The performance of wheat varieties for grain appearance score (maximum score 10.0) under irrigated and drought stress conditions is shown in Table 1. The grain appearance score of WH 1105 was 5.9 and remained the same under irrigated and drought condition while in WH 1025 the score was 6.1 and 5.9 under irrigated and drought conditions respectively and it was observed that the score was slightly decreased under drought stress conditions.

Hectolitre weight. The hectolitre weight (kg/hl) of both the wheat varieties under irrigated and drought stress conditions are given in Table 1. Hectolitre weight decreased under drought stress conditions. In WH 1105 it decreased from 77.6 to 75.7 and in WH 1025 from 79.7 to 76.6 under irrigated and drought conditions respectively.

Grain hardness. Grain hardness (kg/seed) decreased under drought stress (Table 1). The values recorded for WH 1105 were 9.3 and 8.7 and for WH 1025, 10.5 and 10.0 under irrigated and drought stress conditions respectively. The percent reduction in grain hardness was more in WH 1105 (6.45) compared to WH 1025 (4.76).

Table 1: Effect of drought stress on grain appearance, hectolitre weight, and grain hardness of wheat.

Sr.No.	Variety	Grain Appearance Score (Maximum score 10.0)	Hectolitre weight (kg/hl)	Grain hardness (Kg/seed)
1.	WH 1105- Irrigated	5.9	77.6	9.3
2.	WH 1105 -Drought	5.9	75.7	8.7
3.	WH 1025- Irrigated	6.1	79.7	10.5
4.	WH 1025-Drought	5.9	76.6	10.0
	CD at 5%	G= 0.1, E= 0.1, GXE= 0.1	G= 0.9, E= 0.9, GXE= NS	G= 0.6, E= NS, GXE=NS

Crude protein content: Effect of drought stress on protein content is depicted in Table 2. Protein content increased under drought stress conditions in both the wheat varieties. The protein content observed was 12.6 and 13.4 percent under irrigated and drought conditions respectively with a percent increase of 5.97 in WH 1105. While in WH 1025 the value observed was 12.6 and 12.8 percent under irrigated and drought stress conditions respectively with a percent increase of 1.56 which was a minimum enhancement compared to WH 1105.

Wet gluten: Wet gluten content (%) of both the wheat varieties under irrigated and drought stress conditions is shown in Table 2. Consistent enhancement in wet gluten content was observed under drought stress over the irrigated conditions. WH 1105 showed 26.3 and 28.8 percent and WH 1025 showed 26.0 and 27.2 percent wet gluten content under irrigated and drought stress conditions respectively. The percent increase was lower (4.41) in WH 1025 compared to WH 1105 (8.60).

Dry gluten: Dry gluten content (%) of both the wheat varieties under irrigated and drought stress conditions is shown in Table 2. The dry gluten content followed a similar pattern to that of wet gluten content, where consistent enhancement in dry gluten content was observed under drought stress conditions over the irrigated conditions in both the wheat varieties. In WH 1105 the dry gluten content was 9.2 and 9.8 percent, while in WH 1025 it was 9.1 and 9.3 percent under irrigated and drought stress conditions respectively. WH 1105 showed a maximum increase (6.12 percent) than WH 1025 (2.15 percent).

Table 2: Effect of drought stress on crude protein, wet gluten, and dry gluten of wheat.

Sr. No.	Variety	Crude Protein (%)	Wet Gluten (%)	Dry Gluten (%)
1.	WH 1105- Irrigated	12.6	26.3	9.2
2.	WH 1105 -Drought	13.4	28.8	9.8
3.	WH 1025- Irrigated	12.6	26.0	9.1
4.	WH 1025-Drought	12.8	27.2	9.3
	CD at 5%	G= NS, E= NS, GXE= NS	G = NS, E = 0.8, GXE=NS	G = NS, E= 0.3, GXE=NS

DISCUSSION

Grain quality is expressed through a complex of indices including its physical condition, chemical composition, and biochemical characteristics which are very specific. Quality is susceptible to prevailing environmental conditions of which drought stress is one such factor.

Grain hardness and grain appearance score account for the physical appearance of the grains (Devinder & Raj, 2015). Grain appearance score (GAS) was a subjective test to collectively rate size, shape, soundness, color, and texture out a total score of 10. As per the observations of the present study parameters like grain appearance, hectolitre weight and grain hardness slightly decreased or remained unchanged under drought stress conditions over irrigated conditions (Table 1). Liu *et al.,* (2003) reported the grain appearance score of 8.5/10 in wheat. The results of the present study are at par with the previous results of Mithat & Gluden (2012) who reported that the hectolitre weight of grains was not significantly affected by the nitrogen application and drought stress. Tosun *et al.,* (2006) found a slight but not significant increase in the hectolitre weight of wheat under drought stress. Muhammad *et al.,* (2019) were significantly recorded a high grain appearance score and hectolitre weight in H1 1544 wheat varieties. Improved grain appearance score had also been reported by Mohan *et al.,* (2017). Grain hardness is an important factor that improves the end-use quality of wheat. It has been reported that drought stress increases grain hardness (Weightman *et al.* 2008). Gamila *et al.,* (2021) were also reported that the grain hardness was increased under drought stress due to less accumulation of starch content. In contrast, the present study clearly indicated that drought stress has less effect on grain hardness. Similar results are also reported by Faryad *et al.* (2011).

Grain protein and gluten quality are two important parameters that are affected by drought stress. Variation in protein content and composition significantly modify flour quality for bread making (Weegels *et al.* 1996; Branlard *et al.* 2001). Thus, high grain crude protein content is privileged since there is a linear relationship between flour protein content and bread-making quality. The results presented in Table 2 show that crude protein content slightly increased under drought stress conditions. The results are consistent with that of Francois *et al.* (1986) in durum wheat. Darvey *et al.* (2000) similarly showed that salinity significantly influences protein content and caused an increase in protein content. An increase in grain protein percentage in the present study due to drought stress may be attributed to reduced starch accumulation. Similarly, other workers (Guittieri *et al.* 2005; Krisztina *et al.,* 2011; Maryam & Ahmad 2013) reported increased protein content under drought stress. On par with our results were also reported by Abdul *et al.,* (2020), where they showed an increase of grain protein content under drought stress conditions. In contrast, Pierre, (2008) observed decreased value for grain protein in wheat grown under drought stress. Hasan & Tacettin, (2010) also reported that drought stress conditions increased protein content in wheat as compared to well-watered conditions.

The results of wet gluten content are given in Table 2. Drought stress increased wet gluten content in both the wheat varieties. However, a higher increase was observed in WH 1025 than WH 1105. Jahangir *et al.,* (2013) reported wet gluten content of 29.91 percent in drought tolerant Tijaban 10 wheat cultivar. The results pertinent to dry gluten are given in Table 2. Drought stress increased dry gluten content in both the wheat varieties however, more percent increase was observed in WH 1025 as compared to WH 1105 indicating that dry gluten content was substantially affected in this variety. Katerji *et al.,* (2005) observed that the gluten content of salt-sensitive and tolerant durum wheat varieties was not affected by salinity. Maryam & Ahmad (2013) reported that salt stress caused an increase in dry gluten content of the wheat genotypes. A positive correlation of grain protein content with dry and wet gluten content was reported by Haji *et al.,* (2020).

CONCLUSIONS

— Grain appearance score of WH 1105 is unchanged under irrigated and drought conditions while the score is slightly decreased in WH 1025 under drought stress condition.
— Hectolitre weight decreased under drought stress with more decrease was observed in WH 1025 as compared to WH 1105.
— Grain hardness decreased under drought with more decrease in WH 1105 than WH 1025.
— Crude protein and gluten content increased under drought stress with more increase was observed in WH 1105 than WH 1025.

FUTURE SCOPE

Further experiments are needed to completely evaluate other quality parameters of wheat grains affected by drought stress in WH 1105 and WH 1025 and the obtained data can be used as traits for different plant breeding programs to develop better drought-tolerant varieties.

Conflict of Interest. The authors declare no conflict of interest.

Acknowledgments. The financial support received from CCS Haryana Agricultural University-Hisar is duly acknowledged. The authors also acknowledge the help received from the Department of Crop Physiology, CCSHAU-Hisar for extension of field and laboratory facilities. Special thanks are due to Karnam Chinna Babu for proofreading and preparation of the manuscript.

REFERENCES

Abdul, S., Ahmed, S., Muhammad, I., Malik, S. U., Niaz, A., & Ummed, U. U. (2020). Individual and combined effect of terminal drought and heat stress on allometric growth yield and quality of bread wheat. *Pakistan Journal of Botany*, *52*(2): 405-412.

AOAC, (2000). *Official method of analysis*. 17th Ed. Inc., Maryland, USA.

Benjamin, J. G., & Nielsen, D. C. (2006). Water deficit effects on distribution of soybean, field pea and chickpea. *Field Crops Research*, *97*: 248-253.

Branlard, G., Drdevet, M., Saccomano, R., Lagoutte, F., & Gourdon, J. (2001). Genetic diversity of wheat storage proteins and bread wheat quality. *Euphytica*, *119*: 59-67.

Darvey, N.L., Naeem, H., & Gustafson, J. P. (2000). Triticale production and utilization, In Klup, K.P.J. (eds.). *Handbook of Cereal Science and technology*. 2nd Edn. Marcel Dekker: New York. pp. 257-274.

Devinder, M., & Raj, K.G. (2015). Assessment of non-grain parameters in wheat quality under diverse climate of India. *Journal of Wheat Research*, *7*(1): 59-65.

Faryad, A., Naeem, I., Makhdoom, H., & Javed, A. (2011). Grain quality attributes of wheat lines having differential photosynthetic efficiency under prolonged drought stress. *Pakistan Journal of Botany*, *43*(5): 2485-2489.

Farzad, A., Mogammad, R. M., & Abdul, S. J. (2012). Evaluation of some morphological traits associated with wheat yield under terminal drought stress. *African Journal of Agricultural research*, *7*(28): 4104-4109.

Francois, L. E., Mass, E. V., Donovan, T. J., & Young, V. L. (1986). Effects of salinity on grain yield and quality, vegetative growth and germination of semi-dwarf and durum wheat. *Agronomy Journal, 78*: 1053-1058.

Gamila, M. I. D., Nasrein, M. K., Yasir, S. A. G., Yuji, Y., Yusuke, B., Keito, K., Izzat, S. A. T., Takayoshi, I., Hiroyaki, T., & Hisashi., T. (2021). Novel loci for kernel hardness appeared as response to heat and combined heat-drought conditions in wheat harboring *Aegilops tauschii* diversity. *Agronomy, 11*: 1-21.

Ghulam, M .L., Fateh, C. B., Shamsuddin, T., Qamaruddin, C., Allah, W. G., Muzzammil, H. S., Syed, W. V. H., & Abid, A. (2011). Growth and yield attributes of wheat at different seed rates. *Sarhad Journal of Agriculture*, *27*(2): 177-183.

Guittieri, M. J., McLean, R., Stark, J. C., & Souza, E. (2005). Managing irrigation and nitrogen fertility of hard spring wheat for optimum bread quality. *Crop Science*, *45*: 2049-2059.

Hafiz, M.A., Abdus, S., Abbas, A., & Mushtaq, N. (2012). Agro-physiological performance of wheat genotypes under normal moisture and drought conditions. *Iranian Journal of Plant Physiology*, *2*(2): 361-369.

Haji, M. U. M., Saqib, A., Hadi, B., Mahboob, A. S., Ali, M. R., Wazir, A. M., & Mujataba, S. M. (2020). Variability of some Pakistan commercial wheat (*Triticum aestivum L.*) varieties for agro-morphological and end-use quality traits. *Pakistan Journal of Botany*, *52*(2): 581-592.

Hasan, K. and Tacettin, Y. (2010). The effect of drought stress on grain yield, yield components and some quality traits of durum wheat (*Triticum turgidum* sp. *Durum*) cultivars. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 38(1): 164-170.

Hui, Z., Tingbo, D., Qi, J., & Dong, J. (2007). Leaf senescence and grain filling affected by post-anthesis high temperatures in two different wheat cultivars. *Plant Growth Regulation*, *51*: 149-158.

Imran, H., Muhammad, A. S. R., Rashid, I., Muhammad, U. A., Muhammad, H. V. R., Shameem, R., Muhammad, T. K., Muhammad, M. A., Muhammad, W., & Salman, A. (2020). Potential effect of biochar application on mitigating the drought stress implications on wheat *(Triticum aestivum L.)* under various growth stages. *Journal of Saudi Chemical Society, 24*(12): 974-981.

Ivanova, A., Tsenov, N., & Stoeva, I. (2013). Grain quality of common wheat according to variety and growing conditions in the region of Dobruzha. *Bulgarian Journal of Agricultural Science*, *19*(3): 523-529.

Jahangir, K., Saifullah, K., Munir, A. K., Nadeem, S., Mohammad, I., Abdul, H., & Ahmad, A. (2013). Tijaban-10A Drought tolerant and high yielding wheat variety for rainfed/sailaba areas of Balochistan. *Pakistan Journal of Botany, 45*(4): 1357-1362.

Jian, Y. W., You, C. X., Feng, M. L., Kadambot, H. M. S., & Neil, C. T. (2017). Effect of drought stress on morphological traits, biochemical characteristics, yield and yield components in different ploidy wheat: A meta-analysis. *Advances in Agronomy*, *143*: 139-173.

Katerji, N. Van-Hoorn, J. W., Fares, C., Hamdy, A., Mastrosilli, M., & Oweis, T. (2005). Salinity effect on grain quality of two durum wheat varieties differing in salt tolerance. *Agriculture Water Management, 75*: 85-91.

Krisztina, L. F., Andrew, C., & Antony, B. (2011). Quantitative proteomic analysis of wheat cultivars with differing drought stress tolerance. *Plant Science*, *2*: 1-11.

Liu, J. J., He, Z. H., Zhao, Z. D., Pena, R. J., & Rajaram, S. (2003). Wheat quality traits and quality parameters ofcooked dry white Chinese. *Euphytica, 131*: 147-154.

Marshall, D.R., Mares, D. J., Moses, H. J., & Ellison. F. W. (1986). Effects of grain shape and size on milling yields in wheat II. Experimental studies. *Australian Journal of Agricultural Research*, *37*(4): 331-342.

Maryam, S., & Ahmad, A. (2013). Grain quality traits in triticale influenced by salinity stress. *Australian Journal of Crop* Science, *7*(5): 580-587.

Mehmet, Y., Celeddin, B., Mujde, K., Halef, D., Akbar, H., Mohammed, S. I., Tren, T., Onder, A., Cuma, A., & Ayan, E. S. (2018). Assessment of grain quality of wheat genotypes grown under multiple environments using GGE biplot analysis. *Fresenius Environmental Bulletin*, *27*(7): 4830-4837.

Mithat, N. G., & Gluden, D. A. (2012). Effect of post anthesis drought on certain agronomical characteristics of wheat under two different nitrogen application conditions. *Turkish Journal of Field Crops, 17*(1): 19-23.

Muhammad, Y., Satish, K., Dhaka, A. K., & Axay, B. (2019). Effect of sowing dates and varieties on yield and quality performance of wheat (*Triticum aestivum* L.) *Agricultural Science Digest, 39*(4): 306-310.

Mohan, D., Tiwari, V., & Gupta, R. K. (2017). Progression in yield and value addition of Indian bread wheat-An analysis. *Indian Journal of Genetics*, *77*(1): 16-24.

Nezar, H. S. (2005). Effects of drought stress on growth and yield of barley. *Agronomy and Sustained Development,* (1): 145-149.

Ninai, S., Piere, S., Mathew, J. R., & Mikhai, A. S. (2019). Drought tolerance during reproductive development is important for increasing wheat yield potential under climate change in Europe. *Journal of Experimental Botany, 70* (9): 2549-2560.

Ozturk, A., & Aydin, F. (2004). Effect of water stress at various growth stages on some quality characteristics of winter wheat. *Journal of Agronomy and Crop Science*, *190*: 93-99.

Prabha, M. L., Cairns, J. E., Babu, R. C., & Lafitte, R. (2009). Identification of physiological traits underlying cultivar differences in drought tolerance in rice and wheat. *Journal of Agronomy and Crop Science*, *195*: 30-46.

Pierre, B. (2008). Positive contribution of stem growth to grain number per spike in wheat. *Field Crops Research, 105*: 27-39.

Richard, M. W., Sam, M., Juan, A., John, F., Lesley, F., & John, W. S. (2008). Effects of drought and presence of 1DL/1RS translocation on grain vitreosity, hardness and protein content in winter wheat. *Journal of Cereal Science*, *47*(3): 457-468.

Tosun, M., Yuce, S., Erkul, A., & Ege, H. (2006). The indirect selection efficiency against direct selection of some agronomic and quality characteristics of wheat which is grown under irrigated and dry conditions. *Journal of Ege University Faculty of Agriculture*, *43*: 53-62.

Weegels, P. L., Hamer, R. J., & Schofield, J. D. (1996). Critical review: functional properties of wheat glutenin. *Journal of Cereal* Science, *23*: 1-18.

Weightman, R. M., Millar, S., Alava, J., Foulkes, M. J., Fish, L., & Snape, J. W. (2008). Effects of drought and presence of the IBL/IRS translocation on grain vitreosity, hardness and protein content in winter wheat. *Journal of Cereal Science*, *47*: 457-468.

Yashawanthkumar, K. J., Vijendra, S. B., Sudhir, N., Ravindra, M. P., Juned, H. B., Deepak, N. B., Vittal., D. G., Gopalareddy, K., Chandra, N. M., Marutha, H. M., Sanjay, K. S., Shreenivas, A. D., & Gyanendra, P. S. (2021). Impact of heat and drought stress on phenological development and yield in bread wheat. *Plant Physiology Reports, 26*: 357-367.

How to cite this article: Rao, D.S., Raghavendra, M., Gill, P., Madan, S. and Munjal, R. (2021). Effect of Drought Stress on Grain Quality Attributes in Wheat (*Triticum aestivum L.*) varieties. *Biological Forum – An International Journal, 13*(3): 58-63.