APPL. SCI. BUS. ECON.
ISSN 2312-9832

APPLIED SCIENCES AND BUSINESS ECONOMICS

OPEN ACCESS

Pictorial Review of Critical Stages at Vegetative and Reproductive Growth in Wheat for Irrigation Water Regimes

Hamid Nawaz[1], Nazim Hussain[*1], Azra Yasmeen[1], Muhammad Ishaq Asif Rehmani[2] and Hafiz Muhammad Nasrullah[3]

[1]*Department of Agronomy, Bahauddin Zakariya University, Multan, Pakistan*
[2]*Department of Agronomy, Ghazi University, Dera Ghazi Khan, Pakistan*
[3]*Agronomic Research Station, Regional Agriculture Research Institute, Bahawalpur, Pakistan*

***Corresponding author email**
nazimhussain@bzu.edu.pk

Keywords
sensitive growth phases, *Triticum aestivum*, drought

Abstract

Drought becomes a major threat among the environmental stressors and reduces the wheat (*Triticum aestivum* L.) productivity worldwide. Scientists predicted the sudden globally climate change emphasized the water resources, mining the availability of water and episodes the drought spells. Water deficit at the critical wheat growth stages including vegetative and reproductive growth stages impedes the sever loss in grain yield. Reduction of yield in wheat determined through the severity of drought duration at the sensitive stages of wheat. The present review study explored the need and importance of irrigation water regimes at the critical growth stages of wheat for agricultural scientists as well as the best management practices for the farmers. The review contains ten important the progressive key stages in the life cycle of the wheat plant. Each chapter contains following more minor stages such as germination, (dry seed, start of imbibition's, radical emergence from seed, imbibition's complete, coleoptiles emerged from seed, leaf just at coleoptiles tip) seedling growth stages (1st leaf through coleoptiles, first leaf emerged unfolded, 2 leaf unfolded, 4 leaf unfolded, 8 leaf unfolded), tillering (main shoot only, main shoot and 1st tiller, main shoot and 2 tillers, main shoot and 4 tillers, main shoot and 8 tillers), stem elongation (stem start to elongate, 1st node detectable, 2nd node detectable, 4th node detectable, flag leaf just visible, flag leaf/collar just visible), booting stage head emergence anthesis or flowering milk development (dough development, ripening, (seed hard, difficult to divide with thumb nail, seed halt can no longer be detente by thumb nail), harvesting. Included in each stages are practical exercises to demonstrate how knowledge of plant physiology can be applied in the field and which stage is most critical for irrigation under stress conditions.

.

1 Introduction

Water scarcity is one of the most prominent environmental harsh stresses in Pakistan as well as in the most of world regions which gradually reduces wheat germination, growth, development and productivity. Drought is becoming a crucial threat for the agricultural scientists and farmers (Economic Survey of Pakistan, 2015). It is estimated till 2015; approximately 1.9 billion people suffered absolute water shortage and 68% world population under water-stressed environments (Angus et al., 1981). Due to the mining of the water, staple crops are badly affected and decreased the economy and human consumption up to the mark (Dhanda and Sethi, 2002). Wheat is the major cereal crop sown in winter season based on the suitable climatic conditions as temperature 25-30 $^{\circ}$C in Pakistan (Nawaz et al., 2015a). Maximum

reduction in the wheat especially is due to the mismanagement of water application. It is necessary to apply the water at the critical growth stages of wheat which performed better in the yield and yield components. Application of irrigation at the critical growth stages in wheat is not only valuable information for the farmers even in the production aspects, it also important for the saving the water (Ashraf and Leary, 1996.). Different scientists worked for determine the critical growth stages as The Feeks scale (Acevedo, 1987; Bagga and Rawson, 1977), a growth stages of wheat facilitates the farmers, advisers, researchers with common time duration and specific shape for the describing the crop development (Acevedo, 1991; Baker and Gallagher, 1983). Management by the growth stages is the critical to optimize returns from the inputs such as water, fertilizer, plant growth regulators and fungicides (Abbate et al., 1995).

This information has been emphasized as the part of Bahauddin Zakariya University (BZU) funding project examining the role of water management at the need of wheat critical growth stages in Pakistan. Discussion and pictorial portion are primarily based knowledge generated during 2012-2013 under control greenhouse environment in the Department of Agronomy, Faculty of Agricultural Sciences & Technology, Bahauddin Zakariya University Multan, Pakistan. This review study is designed to give the farmers, growers, researchers, scientists and student's confidence knowledge in the identifying the critical growth stages of wheat and also illustrated the relation of growth and development activities under water requirement.

2 Critical Growth Stages

2.1. Germination

Germination starts with the uptake of water (imbibitions) by a wheat grain has lost its post-harvest dormancy (Berry and Rawson, 1981). Plant germination is resumed once the embryo is fully imbibed with the resumption of growth, the radical and coleoptiles emerge from the seed (Biscoe, 1988). The first three seminal roots are produced and then the coleoptiles elongate pushing the growing point toward the soil surface (Blum, 1988). Water deficit at this stage decreased 12% grain yield (Rajaram, 2001). It consists of various stages shown in fig. 1.

2.2. Seedling elongation with tillering establishment stages

The seedling stage begins with the appearance of the first leaf and ends with the emergence of the first tiller (Bouaziz and Hicks, 1990). Tillering has great agronomic importance in cereals crop since it may partially or totallycompensate the differences in plant number after crop establishment (Boyer, 1982). Wheat tillers grow from the axils of the main shoot leaves. The potential number of tillers varies with genotype, particularly among flowering types, winter types having a bigger number (Byerlee and Moya, 1993). Grain yield might be affected approximately 26-74% due to minimum plant population at this stages under limited water regimes (Larbi and Mekliche, 2004). (Fig. 2)

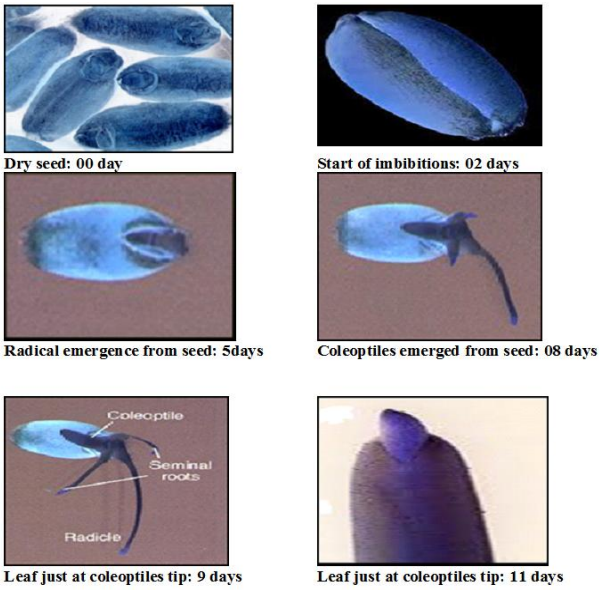

Fig: 1 Germination phases during wheat growth stages Nick Poole, (2009)

2.3. Stem Elongation

The nodes from which leaves develop are telescoped at the crown during the tillering stage (Levitt, 1972). Once jointing starts, the internodes region elongates, moving the nodes and the growing point upward from the crown to produce a long stiff stem that will carry the head (Cao and Moss, 1994). Appearance of the first node can usually be detected without dissecting the plant by pressing the base of the main (largest) stem between your fingers (Condon and Richards, 1993).

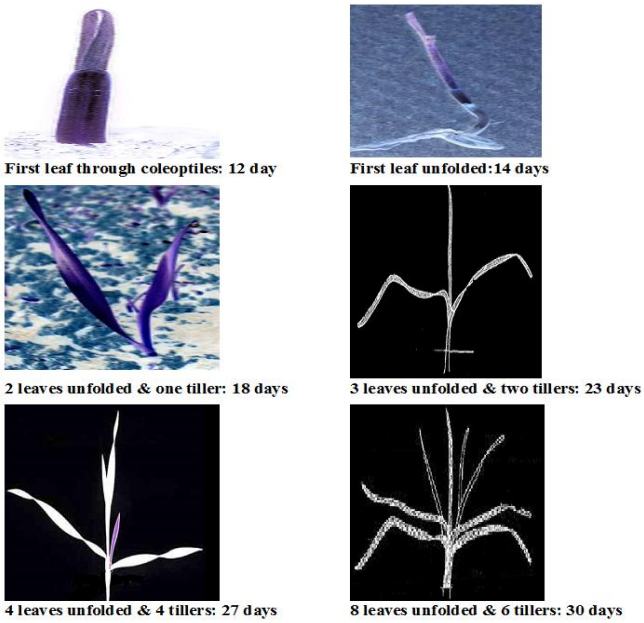

Fig: 2 Seedling elongation with tillering establishment phases during wheat growth stages Nick Poole, (2009)

Each successive tiller of wheat plant normally has one less leaf than its predecessor (Chhipa and Lal, 1995). This synchronizes the start of the stem elongation stages of the main stem and tillers. Spikelet development on the microscopic head is usually completed by the time the first node is 0.4 inches (1 cm) above the soil surface (Dhillon and Ortiz-Monasterio, 1993). A rapid loss of younger, poorly developed tillers also normally starts at this stage (Eastham et al., 1984). The stem elongation or jointing stage comes to an end with the appearance of the last (flag) leaf (Eberhart and Russell, 1966). It is the important stage for wheat growth and development and impaired the yield about 48% under water deficit condition (Fischer, 1983). (Fig. 3)

2.4 Booting stage

Booting stage is the swelling of the head within the 'boot' formed by the sheath of the fully extended flag leaf (Fischer and Maurer, 1978). The developing head within the sheath of the flag leaf becomes visibly and enlarged during the booting stage (Gallagher and Biscoe, 1978). The booting stage ends when the first wheat awns emerge from the flag leaf sheath and the head starts to force the sheath open (Hanft and Wych, 1982). Booting stage is the most critical and sensitive stage of wheat, plant at this stage reduced the grain yield 38% (Shamsi et al., 2010). (Fig. 4)

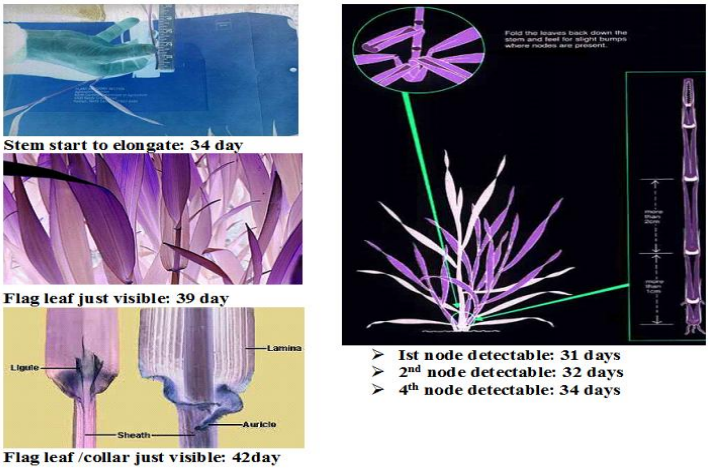

Fig: 3 Seedling establishment phases during wheat growth stages Nick Poole, (2009)

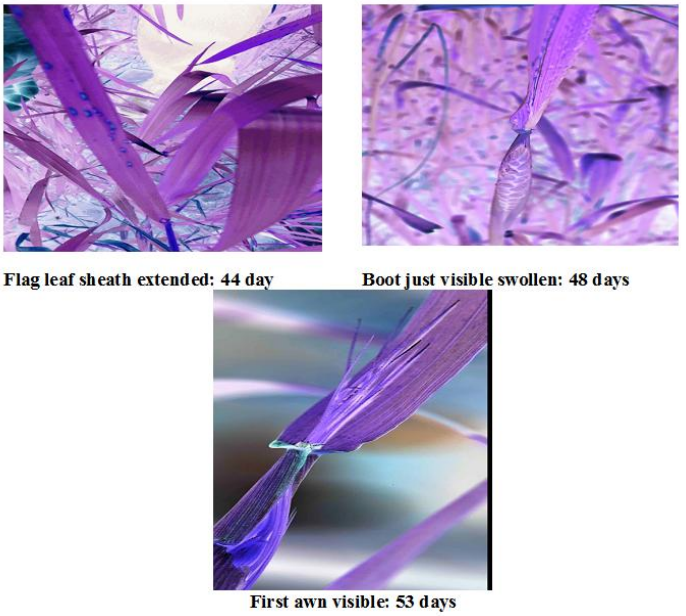

Fig: 4 Booting phases during wheat growth stages Nick Poole, (2009)

2.5. Head Emergence

The heading stage extends from the time of emergence of the tip of the head from the flag leaf sheath when the head has completely emerged but has not yet started to flower (Idso et al., 1984). Heading stage is the second important reproductive stage after booting and most sensitive for drought and minimized the yield about 58-91% (Nawaz et al., 2015b; Balla et al., 2011). (Fig. 5)

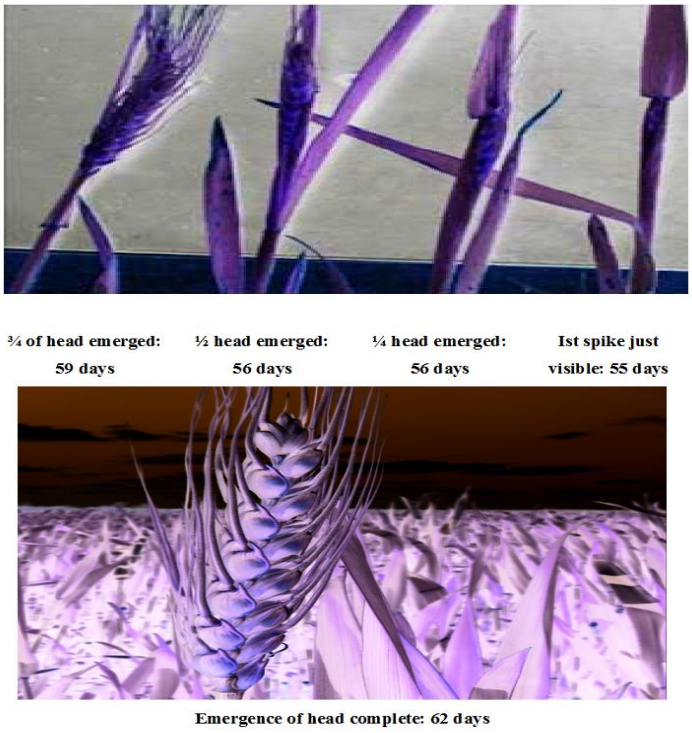

Fig: 5 Heading phases during wheat growth stages Nick Poole, (2009)

2.6 Anthesis or flowering

The flowering or anthesis stage lasts from the beginning to the end of the flowering period. Pollination and fertilization occur during this period (Cattivelli et al., 2008). All heads of a properly synchronized wheat plant flower within a few days and the embryo and endosperm begin to form immediately after fertilization (Liang et al., 2001). Water scarcity at the reproductive growth stages called as terminal drought and anthesis is the prominent in this regard and decreased the yield approximately 18-58% (Majid et al., 2007; Akram, 2011; Jatoi et al., 2011). (Fig. 6)

2.7 Milk Development

Early grain formation occurs during the milk stage (Gupta et al., 2001). The developing endosperm starts as a milky fluid that increases in solids as the milk stage progresses (Eskandari and Kazemi, 2010). Grain size increases rapidly during this stage (Guoth et al., 2009). At the early milk stage the grain is almost grown to its full length and is one tenth of its final weight. Filling continues, and by the medium milk stage, 11 to 16 days after flowering, the grain is half grown. Drought reduced the grain yield about 9-35% under this stage of wheat (Shamsi and Kobraee, 2011). (Fig. 7)

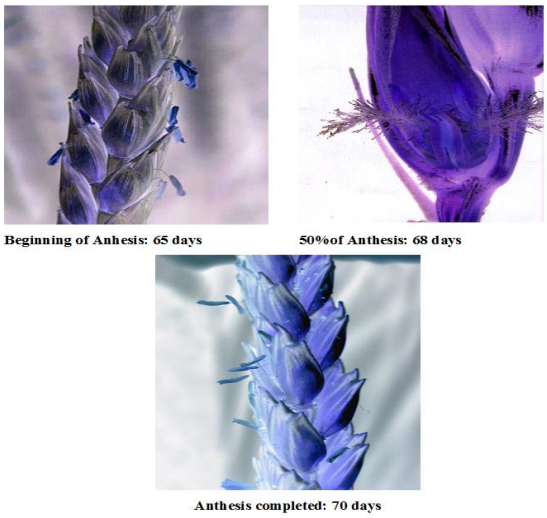

Fig: 6 Anthesis phases during wheat growth stages Nick Poole, (2009)

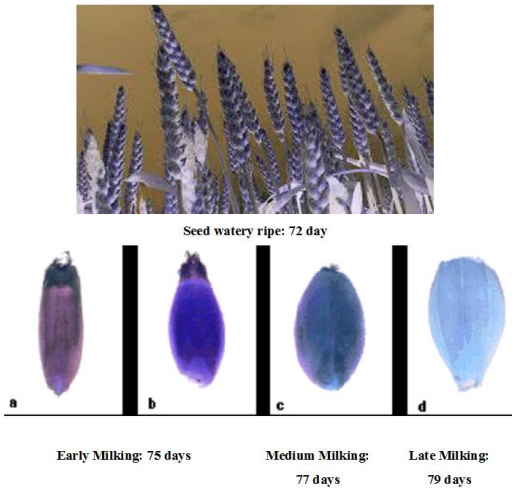

Fig: 7 Milk development phases during wheat growth stages Nick Poole, (2009)

2.8 Dough Development

Grain formation is completed during the dough development stage. The grain accumulates most of its dry weight during dough development (Farooq et al., 2011). The transport of nutrients from the leaves, stems, and spike to the developing seed is completed by the end of the hard dough stage (Wei et al., 2010). The developing grain is physiologically mature at the hard dough stage

even though it still contains approximately 30 percent water (Yang and Zhang, 2006). (Fig. 8)

- **Early development: 83 day**
- **Soft development: 85 day**
- **Hard development: 87 day**

Fig: 8 Dough development phases during wheat growth stages Nick Poole, (2009)

2.9 Ripening

This stage denotes physiological maturity of the crop. This is followed by spike ripening and grain drying (Karimi and Siddique, 1991). The seed loses moisture, and any dormancy it may have had, during the ripening stage (Saini and Westgate, 2000). (Fig. 9)

2.10 Harvesting

Today's modern, high-capacity combines are designed to do an excellent job of threshing and cleaning wheat grains. However, part of the crop is left in the field or the quality of the grains harvested is less as needed. In most cases, a few minor adjustments can drastically reduce losses or improve grain quality (Kirby and Appleyard, 1984). (Fig. 10)

Fig 9 Ripening phases during wheat growth stages Nick Poole, (2009)

Fig: 10 Harvesting phase during wheat growth stages Nick Poole, (2009)

3 Conclusion

Knowledge about the wheat phenology and physiology of is well known for the agronomist and plant breeders. Inputs priority including irrigation should be given to yield and yield forming processes, with the idea in mind that the application of these concepts would have a higher impact on wheat production around the world.

References

Abbate, P.E., Andrade, F.H. & Culot, J.P. (1995).The effect of radiation andnitrogen on number of grains in wheat. *The Journal of Agricultural Science*, 124, 351-360.

Acevedo, E. (1987). Assessing crop and plant attributes for cereal improvements. In J. P. Srivastava, E. Porceddu, E. Acevedo and S. Varma, eds. Drought Tolerance in Winter Cereals, p. 303-320. Willey.

Acevedo, E. (1991). Morphophysiological traits of adaptation of cereals to Mediterranean environments. In E. Acevedo, E. Fereres, C. Giménez and J.P. Srivastava, eds. Improvement and management of winter cereals under temperature, drought and salinity stress, p. 85-96. Proceedings of the ICARDA-INIA Symposium. Córdoba, Spain.

Ahrens, J.F. & Loomis, W.E. (1963). Floral induction and development in winter wheat. *Crop Science*, 3, 463-466.

Akram, M. (2011) Growth and yield components of wheat under water stress of different growth stages. *Bangladesh Journal of Agricultural Research*, 36, 455-468.

Allison, J.C.S. & Daynard, T.B. (1976). Effect of photoperiod on development and number of spikelets of a temperature and some low-latitude wheats. *Annals of Applied Biology*, 83, 93-102.

Angus, J.F., Cunningham, R.B., Moncur, M.W. & Mackenzie, D.H. (1981). Phasic development in field crops. I. Thermal response in the seedling phase. *Field Crops Research*, 3, 365-378.

Ashraf, M. & O'Leary, J.W. (1996). Responses of some newly develop salt-tolerant genotypes of spring wheat to salt stress: II. Water relation and photosynthetic ccapacity. *Acta Botanica Neerlandica*, 45, 29-39.

Bagga, A.K. & Rawson, H.M. (1977). Contrasting responses of morphologically similar wheat cultivars to temperatures appropriate to warm temperate climates with hot summers. A study in controlled environments. *Australian Journal of Plant Physiology*, 4, 877-887.

Baker, C.K. & Gallagher, J.N. (1983a). The development of winter wheat in the field. Relation between apical development and plant morphology within and between seasons. *The Journal of Agricultural Science*, 10, 327-335.

Balla, K., Rakszegi,M., Li, Z., B´ek´es, F., Bencze, S., & Veisz, O. (2011). Quality of winter wheat in relation to heat and drought shock after anthesis. *Czech Journal of Food Sciences*, 29, 117-128.

Berry, J.A. & Rawson, J.K. (1981). Response of macrophytes to temperature. In O.L. Lange, P.S. Nobel, C.B. Osmond, and H. Ziegler, eds. Physiological PlantEcology. I. Responses to Physical Environment. Springer-Verlag, Berlin. 278 p

Biscoe, P.V. (1988). N-Sure, the selective N-fertilisation for wheat. In Knowledge-Based Systems in Agriculture. Int. DLG-Congress for Computer Technology, p. 401-413. Frankfurt, 19-22 June 1988. Deutsche Landwirtschafts-esellschaft: Frankfurt.

Blum, A. (1988). Plant Breeding for Stress Environments. CRC. Press Inc. Florida, USA. 223 pp.

Bouaziz, A. & Hicks, D.R. (1990). Consumption of wheat seed reserves during and during and early growth as affected by soil water potential. *Plant and Soil*, 128, 161-165.

Boyer, J.S. (1982). Plant productivity and environment. *Science*, 218, 443-448.

Byerlee, D. & Moya, P. (1993). Impacts of international Wheat breeding research in the developing world, 1966-1990. México, D.F.: CIMMYT.

Cao, W. & Moss, D.N. (1994). Sensitivity of winter wheat phyllochron to environmental changes. *Agronomy Journal*, 86, 63-66.

Cattivelli L., Rizza, F., Badeckc, F.W. Mazzucotelli, E., Mastrangelo, A.M.,Franciaa, E.,Mar`ea, C., Tondellia, A., & Stanca, A.M. (2008). Drought tolerance improvement in crop plants: An integrated view from breeding to genomics. *Field Crops Research*, 105, 1-14.

Chhipa, B.R. & Lal, P. (1995). Na/K ratios as the basis of salt tolerance in wheat. *Australian Journal of Agricultural Research*, 46, 533-539.

Condon, A.G. & Richards, R.A. (1993). Exploiting genetic variation in transpirationefficiency in wheat: An Agronomic view. p. 535-450. In J. Ehleringer, A.E. Hall and G.D. Farquhar, eds. Stable Isotopes in Agriculture. Academic Press, USA.

Dhanda, S. S. & Sethi, G. S. (1998). Inheritance of excised leaf water loss and relative water content in bread wheat (*Triticuma estivum*). *Euphytica*, 104, 39-47.

Dhillon, S.S. & Ortiz-Monasterio, J.I. (1993). Effect of date of sowing on the yield and yield components of spring wheat and their relationship with solarradiation and temperature at Ludhiana, Punjab, India. Wheat Special Report N° 23ª. MéxicoD.F.: CIMMYT.

Eastham, J., Osterhuis, D.M. & Walker, S. (1984). Leaf water and turgor potential threshold values for leaf growth of wheat. *Agronomy Journal*, 76, 841-847.

Eberhart, S. & Russell, W. (1966). Stability parameters for comparing varieties. *Crop Science*, 6, 36-40.

Economic survey of Pakistan. (2015). Ministry of Food, Agriculture and Livestock, Islamabad, pp: 15.

Eskandari, H., & Kazemi, K. 2010. Response of different bread wheat (*Triticum aestivum* L.) genotypes to post-anthesis water deficit. *Notulae Scientia Biologicae*, 2, 49-52.

Farooq, M., Bramley, H., Palta, J. A., & Siddique, K.H.M. (2011). Heat stress in wheat during reproductive and grain filling phases. *Critical Review of Plant Science*, 30,491-507.

Fischer, R. A. & Maurer, R. (1978). Drought resistance in spring wheat cultivars. Grain yield responses. *Australian Journal of Agricultural Research*, 29, 897-912.

Fischer, R.A. (1983). Wheat. In Proceeding Symposium on Potential Productivity ofField Crops under Different Environments, p.129-154. Sept. 1980, IRRI, LosBaños.

Gallagher, J.N. & Biscoe, P.V. (1978). A physiological analysis of cereal yield. II. Partitioning of dry matter. *Agricultural Progress*, 53, 51-70.

Gu´oth, A., Tari, I., Gall´e, A., Csisza´r, J., P´ecsv´aradi, A., Cseuz, L., & Erdei, L. (2009). Comparison of the drought stress responses of tolerant and sensitive wheat cultivars during grain filling: changes in flag leaf photosynthetic activity, ABA levels, and grain yield. *Journal of Plant Growth Regulator*, 28, 167-176.

Gupta, N. K., Gupta, S., & Kumar, A. (2001). Effect of water stress on physiological attributes and their relationship with growth and yield of wheat cultivars at different stages. *Journal of Agronomy and Crop Science*, 186, 55-62.

Hanft, J.M. & Wych, R.D. (1982). Visual indicators of physiological maturity of hardred spring wheat. *Crop Science*, 22, 584-587.

Idso, S.B., Reginate, R.J., Hatfield, J.I. & Pinter, P.J. Jr. (1984). Measuring yield reducing plant water potential depression in wheat by infrared thermometry. *Irrigation Science*, 2, 205-212.

Jatoi, W. A., Baloch, M. J., Kumbhar, M. B., Khan, N. U., &Kerio, M. I. (2011). Effect of water stress on physiological and yield parameters at anthesis stage in elite spring wheat cultivars. *Sarhad Journal of Agriculture*, 27, 59-65.

Karimi, M.M. & Siddique, H.M. (1991). Crop growth and relative growth rate of oldand modern wheat cultivars. *Australian Journal Agricultural Research*, 42, 13-22.

Kirby, E.J.M. & M. Appleyard. (1984). Cereal development guide. Arable Unit, National Agriculture Centre, Stoneleigh, Kenilworth. England. 95p.

Larbi, A., & Mekliche, A. (2004). Relative water content (RWC) and leaf senescenceas screening tools for drought tolerance in wheat. *International Centre for Advanced Mediterranean Agronomic Studies*, 60, 193-196.

Levitt, J. (1972). Responses of Plants to Environmental Stresses. Academic Press, New York.

Liang, J., Zhang, J., & Cao, X. (2001). Grain sink strength may be related tothe poor grain filling of indica-japonica rice (*Oryza sativa*) hybrids. *Physiologia Plantarum*, 112, 470-477.

Majid, S. A., Asghar, R., & Murtaza, G. (2007). Yield stability analysis conferring adaptation of wheat to pre- and post-anthesis drought conditions. *Pakistan Journal of Botany*, 39, 1623-1637.

Nawaz H.., Hussain, N., Yasmeen, A., Arif, M., Hussain, M., Rehmani, M.I.A., Chattha, M.B., & Ahmad, A. (2015a).Soil applied zinc ensures high production and net returns of divergent wheat cultivars. *Journal of Environmental and Agricultural Science*, 1, 2313-8629.

Nawaz H., Hussain N., & Yasmeen, A. (2015b) Growth, yield and antioxidants status of wheat (Triticum aestivum L.) cultivars under water deficit conditions. *Pak. J. Agric. Sci.* 52, 953-959.

Nick Poole, (2009). Cereal Growth Stages. Foundation for Arable Research (FAR) pp 1-44.

Rajaram, S. (2001). Prospects and promise of wheat breeding in the 21st century.*Euphytica*, 119, 3-15.

Saini, H.S. & Aspinall, D. (1982). Abnormal sporogenesis in wheat (*Triticuma estivum* L.) induced by short periods of high temperature. *Annual of Botany*, 49, 835-846.

Shamsi, K., & Kobraee, S. (2011). Bread wheat production under drought stress conditions. *Annual Biology of Research*, 2, 352-358.

Shamsi, K., Petrosyan, M., Noor-Mohammadi, G., & Haghparast, R. (2010).The role of water deficit stress and water use efficiency on bread wheat cultivars. *Journal of Applied Biosciences*, 35, 2325-2331.

Wei, T.M., Chang, X.P., Min, D.H., & Jing, R.L. (2010). Analysis of geneticdiversity and trapping elite alleles for plant height in drought-tolerant wheat cultivars. *Acta Agronomica Sinica*, 36, 895-904.

Yang, J., & Zhang, J. (2006). Grain filling of cereals under soil drying. *New Phytologist*, 169, 223-236.

.