

## Effects of Climatic and Agronomic Factors on Yield and Quality of Bread Wheat (*Triticum aestivum* L.) Seed: A Review on Selected Factors

Nadew BB\*

South Agricultural Research Institute, Areka Agricultural Research Centre, Areka, Ethiopia

\*Corresponding author: Nadew BB, South Agricultural Research Institute, Areka Agricultural Research Centre, Areka, Ethiopia, Tel: +251911387536; E-mail: nadewboto@yahoo.com

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### Abstract

The objective of this review work was to explore scientific facts on some of the key climatic and agronomic factors that affect production of quality bread wheat seed. Since it was impossible to cover all production factors once, selection of some of the factors was done. The selected factors for this review were rainfall and temperature among climatic factors while, seed rate and nitrogen fertilization were from agronomic factors. From the investigations of various workers, it could be concluded that rainfall, temperature, seed rate and nitrogen fertilization are some of the key factors that highly influence the state of the physiological processes in seeds and finally affect the yield and quality of seeds.

**Keywords:** Wheat; Seed quality; Rainfall; Temperature; Seed rate; Nitrogen

### Introduction

Wheat (*Triticum aestivum* L.) is grown on 220 million hectares constituting 15.4 percent of the world's arable land (more land area than any other crop) and it is grown in almost all countries and climates. It is the staple food for 4.5 billion people in over 94 countries worldwide. It has the highest content of protein of all the staple cereals and contains essential minerals, vitamins, and lipids. It is the primary source of protein in developing countries where 1.2 billion people are dependent on wheat for survival [1]. It has been projected that the demand for wheat in the developing world will increase 60 percent by 2050 which is a sobering forecast considering global wheat yields have remained constant for more than a decade [2].

A recent analysis by Jayne et al. [3] has also confirmed rapid growth in wheat consumption as a consequence of urbanization, rising incomes, and dietary diversification in Eastern and Southern Africa. However, the productivity of the bread wheat remains low in these countries as compared to the world average yield. The low yield per hectare is attributed to many factors, such as unavailability of quality seed for varieties that are high yielding as well as adapted to wide range of agro-ecologies of the country, use of poor quality seeds (poor quality of farmer saved seeds) and poor agronomic practices are some of the factors [4].

Climatic conditions and the course of the weather influence the quality of wheat grain. For instance, higher starch content was recorded in wheat crop grown in cooler regions at higher altitudes [5]. In contrast, dry weather conditions caused a decrease in yield and a higher proportion of crude protein in the grain [6]. It is now clearly established that grain quality is a function of grain composition, principally in proteins, which depends on the genotype and the environment. The genetic effect is mainly reflected by qualitative variation such as protein polymorphism and secondly by quantitative variation of total protein or of different units and subunits. In contrast,

the environmental effect (growing season, site, fertilization) was mainly reflected by the quantitative variation, such as in total protein or protein unit and subunit contents [7]. Prior to anthesis, environment affects germination, photosynthesis, tiller formation, and inflorescence development, thereby impacting grain number. After anthesis, environmental conditions primarily affect wheat seed size and composition [8].

Generally, poor quality seed may affect the succeeding crop yields in 2 ways: first because emergence from the seedbed may be less than expected, and then plant population density may be sub-optimal, and second because the growth rate of those plants that do emerge may be less than those grown from high quality seeds and become a significant factor affecting wheat productivity. Proper and uniform stand establishment are the key factors for successful crop production in all cropping systems. To ensure such stand, even under adverse conditions, high quality seed must be planted. Seed is a living product and must be grown, harvested and processed correctly to maximize its viability and the subsequent crop productivity. Good quality seed must be sown to realize the yield potential of all varieties. In wheat, the use of quality seed had significantly increased crop productivity by 15-25%. Quality seed leads to lower seed rate, higher crop emergence (>70%), more uniform plant stands, and more vigorous early crop growth. Vigorous growth in early stages reduces weed problems and increases crop resistance to insect pests and diseases that leads to high yields of the crop [9].

Both environmental and agronomical factors highly influence the key physiological processes in seeds under production and finally affect seed yield and quality. Hence, the objective of this review work was to explore the scientific facts on some of the important climatic and agronomic factors that affect production of quality bread wheat seed.

## Discussion

### Selected climatic factors affecting yield and quality of wheat seed

**Effect of rainfall on bread wheat seed yield and quality:** One-third of the world's population is residing in water stressed regions of the world. The hydrological regimes in which crops grow will surely change with global warming. In many environments, water supply is a major source of variability in crop yields. It is globally accepted that rainfall is a leading factor affecting, especially, rain fed crops' productivity [10]. The Agricultural production is affected by many uncontrollable climatic factors, the number one being rainfall. The role of rainfall as a resource in crop production has been an area of interest for many researchers. Rainfall plays a more significant role than other farm inputs. The amount and temporal distribution of rainfall is generally the single most important determinant of inter annual fluctuations in crop production levels [11].

In line with this Arain et al. [12] explained that the impact of rainfall on crop production can be related to its total seasonal amount or its intra-seasonal distribution. In the extreme case of droughts, with very low total seasonal amounts, crop production suffers the most. But more subtle intra-seasonal variations in rainfall distribution during crop growing periods, without a change in total seasonal amount, can also cause substantial reductions in yields. This means that the number of rainy days during the growing period is as important, if not more, as that of the seasonal total. Too much rainfall can cause disease infestation in crops leading to yield and quality loss, while too little can be detrimental to crop yields, especially if dry periods occur during critical development stages. Rainfall can be excess rainfall, scanty rainfall or untimely. The total amount of rainfall in a season is not criteria. But, its distribution over a large area is critical.

Moisture stress during the flowering, pollination, and grain-filling stages is especially harmful to wheat crop. Liu et al. [13] identified the effective climatic factors on wheat yield by giving importance to phenological periods of wheat. His research results showed that wheat yield and quality was affected by average rainfall during seed planting time, flowering and grain-filling time. According to Pan et al. [14] rainfall is commonly considered to be negatively correlated with wheat seed protein content and grain-processing quality. However, wheat seed quality depends on the specific circumstances of the area. When cumulative post-anthesis rainfall is less than 50 mm, it is positively correlated with seed protein content and processing quality; however, when cumulative post-anthesis rainfall is more than 50 mm, contrary results are found.

Similar results have been observed by Wang et al. [15] that high rainfall causes a decrease in grain quality by several ways. First, rainfall prior to grain filling is thought to reduce grain protein content by increasing leaching and other forms of soil nitrogen loss and by diluting early nitrogen reserves in vegetative organs. Second, rainfall may augment soil moisture reserves so that leaf life is extended during grain on-genesis, which favors the assimilation and translocation of carbohydrates more than those of proteins. Third, high amounts of rainfall at harvest raise the percentage of grain sprouting and fungal disease infections of the grain, leading to a significantly reduced seed quality. Fourth, heavy rainfall (over 30 mm d<sup>-1</sup>) at late stages of grain filling, which is likely to be accompanied by subsequent excessive high temperatures, causes a rapid death of wheat roots, sharp grain dehydration, and grain shrinkage and ultimately exerts deleterious

effects on wheat quality [11]. Moreover, Groos et al. [16] stated that continuous rains after seed maturity induce the grain sprouting when it is still on the ear before harvest. This pre-harvest sprouting has been recognized as one of the main factors that decrease the yield and quality of wheat seeds worldwide especially in wet harvest period.

**Effect of temperature on wheat seed yield and quality:** A wheat plant is exposed to many hazards during its lifetime. Low temperatures, high temperatures, drought, and wind are some of the hazards. Losses can be decreased by developing more adaptable varieties and using proper management practices but can never be eliminated entirely. Low temperatures injure wheat by freezing that kill the growing point, and cause sterility of the heads. High-temperature damage is most apparent during grain filling when the kernels are shriveled and prematurely ripen. Numerous studies have investigated the effects of temperature on imbibition and seedling growth and germination [17,18]. It is widely understood for wheat that germination can occur between 4°C and 37°C, with 20°C-25°C seen as the optimum [19]. During imbibition, temperature in part affects the rate of water uptake through the influence of water temperature on its viscosity. After the seed has become physiologically active, temperature affects the kinetics of germination by controlling the rate of the biochemical reactions in the seed.

Temperature has also been shown to affect the rate of seedling emergence in wheat. Lindstrom [20] established a clear relationship between temperature and rate of seedling emergence. He monitored emergence over a range of soil moisture conditions and a range of sowing dates. And he showed that where soil moisture was least limiting there was a clear relationship between emergence and temperature, in wheat production.

Wheat photosynthetic rates are affected by high temperature. High temperature decreases mean photosynthetic rates and mean total biomass [21]. The effect of temperature conditions on the duration and rate of dry matter accumulation in seeds as well as in final seed quality of wheat has been well documented. Seed quality characteristics are significantly influenced by mean temperature during seed development and maturation. Temperatures below and normal alter plant functions and productivity of wheat crop. Short heat stresses ( $\geq 35^\circ\text{C}$ ) in the post-anthesis period can significantly reduce wheat seed weight, decrease wheat seed quality. Moderately high temperatures (25°C-32°C) and short periods of very high temperatures (33°C-40°C and above) during grain filling severely affect the yield, yield components and seed quality in wheat [22].

Much of the variation in seed quality among seed lots is the direct or indirect result of variation in weather before or at harvest, hot dry periods generally providing good quality seed [23]. Accordingly, Ellis and Pieta [24] reported that temperature affects the rate of increase in seed quality during the development and maturation of wheat crop. Evidences consistently reveal that exposure of the parental plant to high temperature influences seed quality. Higher temperature after anthesis adversely affects grain development and growth in wheat because high temperature accelerates initial grain growth rate but shortens the grain growth period. Short period of high temperature stress at reproductive stage reduced the grain quality in wheat. Under controlled conditions, it is estimated that wheat yield decreased by 4% for every 1°C rise in temperature above the optimum. During grain filling stages of late sown wheat, high temperature limits the grain yield because soluble starch synthase involved in synthesis and deposition of starch is extremely sensitive to high temperature and decreases its activity when temperature touches the level beyond 20°C which

decreases grain weight and shrinks wheat yield. As a consequence, smaller and shriveled grains produced are of low vigor and viability if used as seed for next crop [25].

Wheat seed quality is affected by the temperature regime variations in different growth locations. During grain filling, increasing temperature initially had a positive influence on seed protein content. The mechanisms underlying which temperature regimes influence seed protein content have been postulated as; moderately high soil temperature promotes nitrogen uptake from the soil and nitrogen retranslocation from the vegetative parts to the grain; and the optimal temperature for protein biosynthesis is far higher than that for starch biosynthesis [26]. Therefore, moderately high temperatures during grain filling may stimulate seed protein synthesis and protein remobilization from vegetative organs to grains but may reduce photosynthesis and hinder both the conversion of sucrose into starch and the translocation of carbohydrate reserves from vegetative organs to the grain thereby increasing seed protein content [27]. However, daily maximum temperatures exceeding 32°C would reduce the duration of grain on genesis, result in a change in protein composition, produce shriveled grains containing a higher proportion of bran and thus reduce the wheat quality [26].

### **Selected agronomic factors affecting yield and quality of bread wheat seed**

**Effect of seed rate on yield and quality of wheat seed:** Balanced seed rates have a significant role in the seed production system of wheat. Wheat varieties react in different ways to various levels of seed rates. Seed rate affect the plant population, number of tillers m<sup>-2</sup>, 1000 grain weight, and total seed yield. Amanullah et al. [28], Flood et al. [29] found that rate of seeding had a significant influence on 1000 seed weight, the lowest rate producing the heaviest seeds. Agreeing with this, Otteson et al. [30] reported that low seed rate may result in more tillers, more spikelet per spike, high seed yield whereas, inappropriate seed rate leads to low yield and poor quality seed. This is due to higher seed rate leads higher competition for moisture and nutrients, shorter spike length, lower number of grains per spike, and small sized seeds.

The crop sown with bolder seeds (larger seeds) had higher seed germination as compared to the crop sown with small size seeds. This shows that bolder seeds represent the seed quality that resulted in more germinated seedlings as compared to those sown with relatively low quality seed (small size seed) [31]. One of the important criteria in seed vigor is the amount of dry matter or the seed weight. Since germination and seedling emergence requires a lot of energy that is prepared through the oxidation of seed storages, seed should have adequate food supply for seedling growing because seedling until enough growth is dependent to seed [32]. Khan [33] documented that with increasing in seed weight the germination percent increased (i.e., there is positive and significant correlation between seed weight and seed germination percent). Also with increasing in thousand-grain weight, mean of germination time decreased. Highest and lowest mean of germination time of wheat were found with lowest and highest treatment of thousands grain weight, respectively. In line with this Gharineh and Moshatati [34] reported from their seedling growth test that with increasing in thousand grain weight increased significantly the traits of seedling length and seedling dry weight. They claimed that more seedling weight and seedling length of the heavy seeds might be attributed to large food reserves of the seeds sown.

From the aforementioned facts it can be said that seed rate determine the crop vigor, seed size and ultimately yield and quality of the seed. This indicates that the need to determine the optimal seed rate in each growing area as one of the important agronomic managements to improve yield and quality of wheat seed. The improvement in yield and quality is because, proper seed rate encourages nutrient availability, proper sun light penetration for photosynthesis, good soil environment for uptake of soil nutrients and water use efficiency.

**Effect of nitrogen fertilization on yield and quality of wheat seed:** Among the most important management practices influencing grain protein content is N fertilizer application rate and timing. Increasing N fertilizer rates can result in higher grain protein content [35]. Nitrogen plays a very vital role in the process of grain filling, increase leaf area of the crop and result in increased dry matter production by intercepting more sun light [36]. A good supply of nitrogen results in higher net assimilation rate [37], more productive tillers [38], more number of spikes per unit area, number of grains per spike, biological yield and grains yield [39], a higher seed protein content [40]. The response of wheat to N fertilizer also varies with rate and timing of application relative to plant development [37]. Other studies have revealed that seed quality is affected by N application with a profound influence on seed germination capacity [41].

Cox et al. [42] reported that low-input cultivation technology significantly affects grain yield, protein and starch content. High doses of nitrogen increased crude protein content, and reduced the starch content in wheat grain [43]. Studies focused on the effect of nitrogen fertilization showed a high positive correlation between gluten and protein content in flour [44].

Lopez [45] reported that high protein seeds of wheat developed into larger seedlings with a higher dry matter content when grown in N deficient soil. Lowe and Ries [46] also showed a significant positive correlation between wheat seed protein content and dry matter after 3 weeks of seedlings growth. They also reported that seedlings grown from high protein seeds were more advanced in morphological development than seedlings grown from low protein seeds. Lowe and Ries [47] also reported that high protein endosperm produced more vigorous seedlings. Ries et al. [48] reported that increases in seed protein due to N applications were reflected in higher yields the next generation. Schweizer and Ries [49] also reported that seedling growth of wheat was highly correlated with protein content of the seed planted. Ries and Everson [47] reported that both environment and genotype affected the protein content of wheat seed, but regardless of genotype or environment, seedling vigor (dry weight of shoots) was consistently related to seed protein content.

During seed production time, the protein content of seeds can be increased by management practices, the most important of which is rate and timing of N applications. Application of nitrogen later in the season is more effective than earlier application in increasing grain protein content [35]. Application of nitrogen fertilizer near anthesis is more efficient in increasing grain protein content than earlier application [50]. Nitrogen fertilization increase wheat protein contents which is a good indicator of seed quality and vigour [51,52].

Roberts et al. [53] in the Columbia Basin, also found that added increments of fertilizer N in most cases produced increases in grain protein. Although a progressive increase in protein content is obtained by increased application of N, timing of N fertilization according to the



developmental stage of the plant seems to be more important in increasing the protein content.

Different researchers reported increased seed protein when N was applied at different development stages of wheat crop [54] when fertilized at ear emergence, Gomez and De Datta [55] at heading stage, Spratt [56] at flowering stage.

Topdressing N fertilizer at the booting to anthesis stages could increase seed protein content and therefore improve the wheat's seed quality [57]. Nitrogen applications later in the season were more effective than earlier applications in improving protein quality partly because a later fertilization can compensate for the negative effect of excessive rainfall on protein accumulation and seed quality. Protein content may be increased without decreasing yield or seed size by applying split applications of N or combinations of soil and foliar applied N. An early application will insure a high yield and a second application at anthesis will insure high protein content, the optimum timing and rates of soil and foliar applied N, as well as the effects of irrigation, still need to be determined. Adequate seed size may be maintained by a split application of N and sufficient moisture [58]. Increased yielding ability of high protein seeds was also reported by Ries et al. [48]. Because nitrogen is a primary constituent of seed protein, wheat of a high percentage protein is produced only where the crop is provided with an adequate nitrogen supply. So nitrogen is an essential ingredient for producing high quality wheat [59,60].

Thus, a well-balanced supply of N throughout the growing season of the crop is essential for seed production as it has an influence, not only on yield, but also on seed quality, which further affects seed germination capacity, seedling vigor, and the productivity of the succeeding crop.

## Conclusion

Considerable works have been carried out on the effects of climate on agriculture in general. And they tried to show substantial effect of environmental conditions on the chemical composition of wheat seeds. Seeds produced from plants grown under abiotic stress conditions have significantly lower amount of energy in dry matter. The majority of seed quality traits can be greatly affected by a host of environmental factors. Among many climatic factors temperature extremes, rainfall amount, time and uneven distribution, are likely to make the global environment poorer and exert severe influence on crop production quantity and quality in the future.

In addition to climatic factors, agronomic practices such as seed rate and Nitrogen application are also some of the production factors affecting wheat seed quality. Proper seed rate helps to have large sized seeds and nitrogen fertilizer application to wheat crop improves final seed protein percentage. The improved protein contents in seed increase the final germination percentage.

Generally, both environmental and agronomical factors highly influence the key physiological processes in wheat seeds and finally affect yield and quality of seeds. Therefore, a better understanding of the effects of both climatic and agronomic variables on quality traits of wheat crop is likely to become a crucial issue.

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