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Review Article

Improvement of Wheat Production Through Genetic and Environmental Interactions

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Abstract

This study examines tomato genotype variability concerning morphological and biochemical fruit attributes. The Ayub Agriculture Research Institute in Faisalabad, Pakistan has a genetic collection of tomato plants that includes experimental material. Fruit size, locule count, index of fruit form, fruit color, dry matter content, total sugar contents, total acidity, lycopene, and vitamin C content were all examined about genotypes. The key markers of variability (CV and σ) and the minimum, maximum, and mean values were computed. Using principal component analysis, the variability source structure was determined. Four main components that account for 93.74% of the overall variability were chosen for analysis. The definition of the first primary component includes vitamin C, locule number, and fruit form index. Dry matter content and overall acidity decide the second component, whereas lycopene, fruit mass, and fruit color determine the third. The most significant portion of the fourth component was made up of total sugars.

Keywords: Fruit quality; variability; physiological traits; PCA; tomatoes

Introduction

Triticum aestivum and Triticum durum are two types of wheat that are essential protein sources and calories for millions of people worldwide (Arzani & Ashraf, 2017). It provides 18–20% of the world's calories and is a mainstay crop, making a big difference in ensuring enough food for everyone (Rampa et al., 2020). The demand for wheat is likely to keep growing because the world's population and eating habits are constantly changing (Enghiad et al., 2017; Fróna et al., 2019). We currently grow more than 200 million hectares of wheat, the most grains of any crop (Stewart & Lal, 2018). To keep up with the growing demand for food and ensure enough for everyone, it is important to create high-yield wheat types that can handle harsh conditions (Liliane & Charles, 2020; Zörb et al., 2018). Asseng et al. (2017) have found several factors that affect output, such as the number of spikelet's per spike and the weight of 1000 kernels that help wheat grow well. So, to get the highest yields, breeding programs try to make wheat plants with these traits (Venske et al., 2019). However, global wheat yields have decreased since the 1990s, and climate change is still a threat. This means there is a need to quickly create wheat varieties that can handle abiotic stresses like drought, temperature changes, and soil salinization (Kumaraswamy & Shetty, 2016; Mariani & Ferrante, 2017; Sarwar et al., 2021). To solve this problem, scientists have been looking into the different types of wheat and finding genotypes that can handle these stressful situations better and produce more crops (Beres, Hatfield, et al., 2020; Beres, Rahmani, et al., 2020). Molecular markers that can speed up the creation of wheat types that can handle stress are also being looked for in these studies (Raza et al., 2019; Younis et al., 2020). Making high-yielding and stress-resistant wheat types is key to ensuring enough food for everyone worldwide. As the world's population and climate change, we need to quickly create new types of wheat that can thrive in these circumstances. The growth of new wheat types can meet the growing need for food by looking into the genetic diversity of wheat and using molecular markers in breeding programs (Ali et al., 2013; Alipour et al., 2017; Ghafoor et al., 2020; Wani et al., 2022).

Different Techniques use for Crop Yield Improvement

According to experts, improving factors like genotype, surroundings, and phonological traits could raise yields by 43-62%. These factors include how the leaves look, how they react to the length of the days for blooming, how much photosynthesis can happen through the flag leaf area, how well the plant can handle drought, and how well the roots can take water (Iqra et al., 2020; Muqadas et al., 2020; Takeno, 2016). Many experts are working on different types of wheat to improve important traits like photosynthesis and leaf gas exchange, as well as grain number and size. These optimized source and sink traits must work together well to increase food yields. Many characteristics, like the number of tillers per plant, the 1000-kernel weight, the time of flowering, the days until heading, and the length of the spike, have been looked at to see how they affect output (Mathan et al., 2016; Naseem et al., 2020; Nawaz et al., 2020). It is important to know that the number of spikes on a plant is linked to the number of tillers, affecting the grain yield of hexaploid wheat. Furthermore, breeding programs have shown that wheat types with higher grain weight have more chlorophyll pigment, affecting grain weight in direct and indirect ways. Multiple wheat genotypes had grain weights ranging from 20 to 50 g per 1000 kernels in one study (Ali, 2017; Sarwar et al., 2022; Shafique et al., 2020). This was due to grain filling and cell growth through water absorption. Genotypes with better root growth, biomass, and water uptake have higher grain weight and better grain filling. Scientists have also looked at other factors that affect 1000-kernel weight, such as the weight of the carpel at anthesis, the date of anthesis for each flower, and the length of time the grains are filled (Wu et al., 2018).

Genotype Effects on Wheat Yield

Wheat is a significant food item worldwide, a hexaploid plant with the genetic code 2n=6x=42 and a primarily studied family name (Poaceae). The plant is polyploid, which means it has three different genomes, each with two sets of basic chromosomes (2n=2x=14). This species has three genomes: the A genome comes from Triticum urartu, the B genome comes from Aegilops speltoides, and the D genome comes from A. Tauschii. This complicates and is genetically varied (Mirzaghaderi & Mason, 2019). Different types of wheat have different genetic variations that affect their yield. Plant height, the number of tillers and spikelet's, grain weight, and other factors affect wheat's total productivity (Ali et al., 2016). Li et al. (2016) found that the number of spikelets per spike varies between kinds of wheat. The number of tillers per plant can also affect the number of spikelet's and the weight of the grain. Earlier research has shown that several farming and physiological traits are genetically variable. These include plant height, tiller and kernel number, days to maturity, and blooming (Voss-Fels et al., 2019). Genetic prediction works better for smaller groups of people than QTL-based prediction (Norman et al., 2017). Genetic and morphological studies of wheat spike and kernel traits have shown geographical patterns and long-term trends. These studies are mostly about spikelet fertility and kernel/spikelet number, determining the final grain yield. Genome prediction has shown that these qualities are passed down quantitatively and are affected by small-effect QTLs (Moore et al., 2017).

Yield Improvement using GWAS and QTL Mapping

It was hopeful at first that linkage mapping and GWAS would significantly improve grain yield because of how complicated yield is, both genetically and in terms of how it interacts with biotic and abiotic factors in the field. But, despite attempts, this hasn't happened. QTL mapping is a powerful tool for finding specific genome regions and learning about the physiological and genetic processes that control important characteristics (Bhanu et al., 2016). This method works well for quality traits that don't depend on many genes. Additionally, Marker-Assisted Selection using closely related markers or the causing mutation can help choose phenotypes more effectively (Visscher et al., 2021). However, it has been hard to find important QTLs and useful markers for yield. Some studies found that the allele from one parent increased grain output, while others found that the allele from the other parent did a better job. We don't fully understand the natural factors that cause this variation yet. Some things that could change are the number of seeds planted, how they are watered, and the stress caused by heat and drought. It's hard to find yield QTLs and useful selection markers, as this shows (Platten et al., 2019; Yang et al., 2020). Focusing on key sites within physiological systems instead of individual QTLs is better than keeping yields stable across various environmental factors (Dwivedi et al., 2020). In places with many terminal droughts, for example, wheat and barley plants may do better if their roots are small to reach deep water in the ground (Daryanto et al., 2017). On the other hand, breeding rice to be more resistant to drought and better at establishing itself in flooded fields could mean making rice plants more resistant to senescence and anaerobic germination (Kumar et al., 2017). These particular traits are more important in specific settings than in terms of progress as a whole. Many links have been found between adaptive traits and field yield (Furbank et al., 2019). So, we must look at the whole picture to determine how genetics affects yield-related traits. This means using methods that combine genetics, physiology, and metabolism to figure out how things work (Sallam et al., 2019). Field testing in natural farming conditions is significant, and using a mix of methods like linkage mapping and GWAS has been shown to work best. It's now easier to do this with the help of freely available datasets and tools (Shadrin et al., 2021). For advanced methods like GWAS and forward and reverse genetic approaches (Kondić-Špika et al., 2023; Walli et al., 2022), high-throughput phenotyping is necessary.

Influence of Biotic and Abiotic Stress Factors on Wheat Yield Healthy Environment Soil Salinization Management

Abiotic stress affecting field crops is mainly caused by salt, with drought being the other major. Indicators like Shankar and Prasad (2023) say this stress can significantly lower food yield, growth, and production. The physical and chemical qualities of the J. Physical Biomed. Biol. Sci. Volume, 2: 8 Abbas et al., (2023) 3 soil, as well as the ecosystem's balance, are also greatly affected. Soil erosion, low food yields, and lower economic returns are some problems that can happen because of salinity stress (El Sabagh et al., 2020). Plants' anatomy, physiology, and biochemistry are all damaged by salinity stress, which makes it harder for seeds to sprout, grow, and take in water and nutrients (Shahid et al., 2020). Ion poisoning, a lack of important elements like N, Ca, K, P, Fe, and Zn, osmotic stress, and less water intake are all caused by it. Beyond that, plants can also be hurt by too much sodium, chlorine, and boron (Chakraborty et al., 2018). Photosynthesis is directly affected as the leaf area, chlorophyll content, and stomatal opening all drop (Chakraborty et al., 2018; Hu et al., 2020). According to Bhattacharjya et al. (2018), salinity stress can also affect reproductive development. It can stop micro-sporogenesis and stamen filament lengthening, cause more tissue cell death, lead to ovule abortion, and slow embryo development. Plants' growth and output are greatly affected by salinity stress. In the worst cases, plants can die, and resources are lost. Two ways plants deal with salinity are by either getting rid of too many salts in their cells or being okay with them being there (Acosta-Motos et al., 2017; Dassanayake & Larkin, 2017). Varying amounts of salt can hurt different foods. Wheat (T. aestivum), a grain that can handle salt, does best in mild climates, while rice (Oryza sativa L.), on the other hand, is susceptible to salt and can't grow in salty places (Hasan et al., 2022). Salt-tolerant crops like barley (Hordeum vulgare) can still die in high salt levels, but durum wheat is not as salt-tolerant as bread wheat (Mwando, 2021). Biochemical, physiological, and molecular levels all show that salt stress hurts plant growth and development as a whole (Dogan, 2020; Isayenkov & Maathuis, 2019).

Effect of Drought Stress

The main reason for drought in agriculture is insufficient water in the root zone, resulting in less production. Drought has many effects that are different in different places. To be able to survive drought, plants need adaptation, which includes the ability to avoid drought and the ability to handle being dry. However; this tolerance differs from salt tolerance (Abobatta, 2020; Asif et al., 2020; Ghafoor et al., 2020; Ilyas et al., 2021; Zubair et al., 2016). Controlling how much the plant absorbs and moves the salt is very important for salt tolerance. Depending on the climate, drought can have different effects on crop production. For example, traits or genes that increase yield in severe drought may not work in moderate drought or may even have adverse effects when there is enough water. For this reason, we need to improve plants' ability to handle drought in certain areas. Plants have many ways to fight off drought, such as controlling the behavior of their stomata, the balance of osmotic pressure, the activity of antioxidants, hormone signaling, miRNA expression, light protection, and metabolic pathways (dos Santos et al., 2022; Kaur et al., 2021). Dry conditions change gene expression and metabolite output, meaning many genes and pathways are involved in this regulatory network. Photosynthesis is crucial during the blooming phase because it creates a good sink potential for later higher output (Ahmad et al., 2021; Ali et al., 2016; Soltani et al., 2019). Many things affect grains, including carbon and nitrogen availability, 10 to 15 days before anthesis. As weather conditions worsen, a lack of water from insufficient rain and groundwater loss are major threats to crop production and food security. To feed everyone, crop production needs to improve, even if there isn't a lot of water available (McAfee, 2019). Because of climate change, droughts, and storms will happen more often, making it even harder to grow food.

Effect of temperature

Stress from heat harms wheat yield. Asseng et al. (2015) say that average world wheat yields will drop by 4 to 6 percent for every 1°C rise in global mean temperature (Zhao et al., 2017). Heat can affect growth and grain filling depending on when and how strong the stress is (Sehgal et al., 2018). Heat stress can make flag leaf photosynthesis less effective, which makes it harder for assimilates to build up and move around. This can lead to a significant drop in grain yield and quality (Feller, 2016).

Effect of Phyto-pathogens

The agricultural sector faces many problems as the world's population grows quickly. Plant diseases can hurt crop output, leading to lower yields, especially for crops used for biofuel and fiber. This can be very bad or long-lasting (Antar et al., 2021). For example, the top six food crops lose an average of 45% of their production. Postharvest disease can also be very bad, especially when it's hard to get to markets, the infrastructure isn't good, and the supply chain isn't working well. Some of these diseases can also make poisons that harm people's health. Experts think that changes in the climate, like global warming, can make plant germs spread faster and cause more damage (Bhadra et al., 2022). According to Petronaitis et al. (2021), these pathogens cause crop losses of 20 to 30 percent annually. This costs a lot of money and affects food security locally, nationally, and internationally. The direct effect of Phytopathogens on grain yields is responsible for 25–45% of all farm production worldwide (Petronaitis et al., 2021).

Effect of Photosynthesis

Photosynthesis has become more and more popular as a way to improve crop yield over the years. Photosynthetic models have helped researchers learn about different parts of photosynthetic leaf gas exchange. Some of these studies are by (Wu et al., 2019)created a diurnal canopy photosynthesis stomatal conductance model that shows how leaf photosynthesis affects crop output in an Australian cropping region in the spring and summer, when J. Physical Biomed. Biol. Sci. Volume, 2: 8 Abbas et al., (2023) 4 water is limite ted and when water is not limited (Wu et al., 2019).

Conclusion

The last few decades have seen a lot of progress in our knowledge of the genes and processes that control important traits that increase crop yield, like the amount and size of grains, the number and function of stomata, the structure of leaves, and the storage of carbohydrates. However, regarding grain output and wheat quality, how genotypes and environmental conditions interact often leaves people guessing what will happen. This is a big problem for systems that look at inbreeding and genotypes. Soil quality, nitrogen supply, rainfall, and temperatures during ripening are critical factors that affect how well different genotypes do. To make a single gene change in wheat work, you need to simultaneously target all three copies of the gene using methods like gene recognition and editing. GWAS and QTL mapping are both thorough ways to increase crop yields, but they haven't significantly impacted total crop productivity yet. Gene editing has a lot of promise, especially regarding decreasing negative yield regulators. Researchers can speed up the creation of drought- and stress-resistant crop types by finding and using new molecular markers. It's important to balance vegetative and root growth for significant output gains and make the most of the carbon allocation processes during grain set and filling. To do this, you need to know how genes and systems work together in the field. Basic study is still ongoing, and gene editing could be helpful. This gives us reason to be hopeful about getting significant yield gains in the future.

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