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ECONOMICALLY IMPORTANT TRAITS OF ONION

HAMMAD M[1], ABBAS A[2*], HUSSAIN N[1], REHMAN AU[2], JAVED MA[2]

[1]PMAS arid Agriculture University, Plant Breeding and Genetics Agriculture Department, Shamsabad, Murree, Road, Punjab Rawalpindi, 46000 Pakistan
[2]Department of Plant Breeding and Genetics, Faculty of Agricultural Sciences, University of the Punjab, P.O BOX. 54590, Lahore, Pakistan
**Correspondence author email address: ali.bukhari91112@gmail.com*

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Abstract *Onions are an important vegetable crop globally, eaten widely for culinary uses and health benefits. They are the most important horticultural crop in India. Onion cultivation involves various economically important rates and socio-economic factors influencing its production. To maximize onion production in India, timely and effective use of inputs is necessary. The study focuses on important parameters such as yield, cost of cultivation, market price, labor cost, land price, government policies, and seed supply. These factors play a vital role in determining the performance of onion production and its economics. The study further analyzed the relationship between yield and cost of cultivation. The higher the yield, the higher the profit for an onion grower. Interspecific hybridization is the best method for transferring the resistance gene to overcome the plant protection agents and protect the onion from diseases, pests, and abiotic stresses. Transferring other metabolites and odor molecules that benefit human health is also important. It increases genetic diversity and also helpful for the improvement of Allium crops. In the present situation, wild relatives can be used to transfer resistance genes and Allium has an untapped gene pool. There is a need to identify genes responsible for haploid induction, develop techniques for chromosome doubling effectively, gynogenic responsive genes, and a methodology to transfer genes from one genotype to the desired genotype.*

Keywords: *Allium cepa, onion, genes, economically, metabolites, vegetable crop*

Introduction

Onion (*Allium cepa*) is economically important, cultivated worldwide, and a significant component of many dishes (Cramer *et al.*, 2021). It is a monocotyledonous crop and very adaptable to diverse environments compared to 1000 species (Benke *et al.*, 2021). The word "*Allium" is* derived from Celtic word "*All*" which means "pungent". Presence of sulfur compounds makes it called *Allium.* Its genus is *Allium*, family Alliaceae, and subfamily alliodeae (Chase *et al.*, 2016). The main center of origin is Central Asia and Mediterranean region, a small center of biodiversity in western North America (Wheeler *et al.*, 2016) genera Allium and its natural habitat found in the Northern hemisphere (Fritsch *et al.*, 2002). In ancient times, onion was used as a medicine, herb, spices, condiment, and ornament (Li *et al.*, 2010). It is a highly consumable crop and produces waste materials such as onion skin, outer fresh scale, roots, bulb bottom part, and undersized bulb (Sharma *et al.*, 2016). Microwave-assisted extraction can be used for anthocyanin recovery (Salem *et al.*, 2020) and phenolic extraction from onion peel (Amado *et al.*, 2014). The primary class in the onion extract is flavonols, which are higher in onion waste than edible portions (Slimestad *et al.*, 2007). Izoaliin, protein, and metiin are responsible for the aroma of onion. 80% of organo-sulfur compounds are due to izoaliin (Ren *et al.*, 2020). Calcium, magnesium, copper, iron, selenium, and sodium are higher, whereas zinc, manganese, and potassium are lower in onion peel than onion bulb (Salem *et al.*, 2023). Na/K ratio is also low, suitable for preventing cardio-vascular diseases (Galdón *et al.*, 2008). In brown skin, onion calcium is found in a high concentration, whereas top-bottom has a high concentration of minerals (Benítez *et al.*, 2011). Onion peel extract benefits human health because it has anti-microbial, anti-inflammatory, anti-oxidant, anti-diabetic, cytotoxicity, and anti-hyperlipidemic properties (Salem *et al.*, 2023). Anti-oxidant activity is linked with the phenolic compounds (Bozinou *et al.*, 2022).

Onion is very sensitive to the biotic and abiotic stress, which causes yield loss. It is estimated that 40% of yield loss in Agricultural products is due to insects, pests, and weeds. Environment and climate change are also causes of yield loss in onion (Chaudhry *et al.*, 2023). Demand for onion is increasing day by day. So, there is a need to develop high-yielding verities that can tolerate biotic and abiotic stress (Singh *et al.*, 2021). As a biennial crop, i,t produces the bulb in the first year, and then the dormancy period starts. In the following season, the dormancy breaks, and meristem transfers into reproductive meristem, so the onion breeding program faces many issues (Cramer *et al.*, 2021). Many approaches have been used to enhance the yield and to produce biotic and abiotic-resistant varieties adaptable to different geographical regions through conventional breeding. But, the need is to enhance the breeding program using genomic tools. Genetic resources such as molecular markers, population development, genetic mapping, and marker-assisted selection can enhance the breeding program (Vasanthaiah *et al*., 2007). Next-generation sequencing of onion bulbs provides a way to enhance the genetic and molecular basis of economically important traits (Finkers *et al*., 2015).

Important commercial traits for onion

Onion bulb traits are economically fundamental and also related to the yield. A study investigated bulb traits like shape, height, weight, and diameter among the 15 landraces of red onion South Western Timiş County. They were selected according to their agro-climatic condition and the soil salinity of that area. They observed significant differences among the bulb traits (Sumalan *et al*., 2014). It is complicated to meet the demand for onion. So, the need is to breed the onion genotypes with high yield, good horticultural traits, and storability. It will help to fulfill the demand, control the prices, provide more income to farmers, and increase foreign exchange. It is a rabi season crop but needs to develop verities suitable for the cropping season to meet national food security and fill the gap between supply and demand (GUPTA *et al* ., 2019). Waste materials from different parts of onion are harmful to the environment, so there is a need to dispose of these wastes to keep the environment clean appropriately. From the waste material, different value-added products, absorbents for pollutants, organic synthesis, and biogas can be produced (Sharma *et al*., 2016).

Complete methodology

To grow a healthy crop of onions, it is important to choose a sunny location with well-draining soil. Before planting, incorporate compost or well-rotted manure into the soil to provide essential nutrients. You can plant either onion seeds, seedlings, or sets. If planting seeds, place them 1/4 inch deep and 2-3 inches apart, while sets should be planted 2 inches deep and 4 inches apart. Regular watering, especially during dry spells, is important for the growth and development of the onions. Fertilize with a balanced fertilizer every 3-4 weeks to provide additional nutrients. When the seedlings reach 2-3 inches tall, thin them to give them space to grow. Place a 2-3 inch layer of mulch around the onions to conserve moisture and control weeds. Once the tops of the onions start to yellow and fall over, it's time to harvest. Store the onions in a cool, dry place for several months to extend their shelf life (Alemu *et al*., 2022). Onions can be grown in spring or early summer and are typically planted as seeds or seedlings.

The best time to plant onions depends on the specific climate and location. Still, as a general guideline, it is recommended to plant them in well-drained soil when the temperature is consistently above 40°F. To ensure optimal growth and maximum yield, onions should be grown in an area with full sup exposure, and soil with a pH between 6.0 to 7.0 (Ikeda *et al*., 2019). Onions are grown for their edible bulbs, a staple in many cuisines and used in various dishes for flavor and seasoning. They are also low in calories, high in vitamins and minerals, and have numerous health benefits. Growing onions can provide fresh produce for personal consumption and be sold as a cash crop for income generation. Additionally, growing onions can improve soil fertility and is an excellent crop to rotate with other plants to manage pests and diseases (Sidhu *et al*., 2019).

Growing onions requires careful attention to several cultural practices to ensure optimal growth and yield. To begin, prepare the soil by ensuring it has good drainage and a pH between 6.0 and 7.0. This can be achieved by loosening the soil and adding fertilizer. Onions can be planted from seeds or seedlings and should be placed in a sunny location with 4-6 inches of space between each plant. Irrigation is crucial, especially during dry spells, but it is important to avoid overwatering to prevent root rot. Regular fertilization, especially during the early stages of growth, is also important to promote healthy growth. Onions are sensitive to competition from weeds, so it is important to keep the surrounding area weed-free and to use mulch to suppress weed growth and retain moisture in the soil. The bulbs are ready to be harvested when the tops of the plants start to yellow and fall over. After digging up the bulbs, allow them to dry in the sun for a few days before storing. In Pakistan, there are several recommended varieties of onions for growing, including Sharmila, Kibriya, Kashi Lal, Hybrid F1 White, Hybrid F1 Red, Giant Yellow, and Hybrid F1 Pyaj. Each variety has unique characteristics and is well-suited for growing in Pakistan's diverse climates and soil conditions. When choosing an onion variety, consider the local climate, soil type, and desired use (e.g. storage, culinary, or ornamental). With proper cultural practices and attention to detail, these recommended varieties of onions can provide a successful and bountiful harvest (Salari *et al*., 2020). Like other crops, onion faces many insect, pest, bacterial, fungal nematode, and viral infections. The main insect pests of onion are Allium leafminer (*Phytomyza gymnostoma* Loew), onion maggot (*Delia antiqua* Meigen), and thrips (*Thrips tabaci* Lind. Fungal diseases are white rot, Fusarium basal rot, Botrytis leaf blight, pink root, purple blotch, black mold, and Stemphyllium leaf blight. Some bacterial onion diseases are sour skin, bulbs, slippery skin, soft rots, center rot, and *Xanthamonas* leaf blight (Schwartz *et al*., 2008). Iris yellow spot caused by the *Iris yellow spot virus* (IYSV) is the main viral disease (Gent *et al* 2006).

To reduce the risk of disease, it is important to practice good agricultural techniques, such as rotating crops, using disease-resistant varieties, and avoiding overhead watering. If an infection is detected, prompt action should be taken to prevent it from spreading and affecting the entire crop. Proactivity makes it possible to grow a healthy and productive onion crop (Kim *et al*., 2018). The processing of onions can result in various by-products, including onion peel, trimmings, juice, and oil. The peel can be recycled as compost or served as animal feed. Trimmings can be transformed into dried onion flakes, granules, or powder. Onion juice has the potential to add flavor to soups, sauces, and dressings, while onion oil can be used in cooking or to create perfumes and fragrances. The specific by-products generated will depend on the processing techniques employed and the intended use of the onions (Zhao *et al*., 2021). It required low temperature during the early growth stage and low temperature during the late growth stage (Rabinowitch & Currah, 2002). Temperature fluctuations affect plant growth, leaf initiation, and emergence (De Ruiter, 1986). Insect and pest causes yield losses, and control through pesticide use is harmful, so the best control is biological control (Mishra *et al*., 2014). Abiotic stresses like salinity, drought, cold, and heat stress affect growth, production, and yield. Salinity through irrigation is also harmful because onion is susceptible to salinity. Bulb development is also affected by water logging condition. Flavor is affected by the surrounding area's climate (Ratnarajah *et al*., 2021). Major cause of yield loss is weed competition. Manual weed eradication is the common method but it is harmful because of the shallow root system. Bulb formation is affected by the weed flush (Dhananivetha *et al*., 2017).

Growth habits

Onion is essential because of its nutritional and medicinal value. It is consumed throughout the world but its production area is limited. Due to the lack of exploitation of heterosis for buld yield, production per unit area is limited. Increasing the size of individual bulbs can increase yield per unit area. This is possible by exploiting heterosis for earliness, bulb size, weight, biotic and abiotic resistance, which can be achieved through hybrid production through the sterility method of cytoplasmic male sterility or genetic male sterility (Manjunathagowda *et al*., 2021).

Genetic variability

In Rabi season, a study was conducted on 19 onion genotypes in the Department of Horticulture Sam Higginbottom Institute of Agriculture, Technology & Sciences, Allahabad. The purpose of this study was correlation, genetic variability, and inheritance, and it includes genetic advance, mean, genotypic variance, phenotypic variance, and genetic inheritance of genetically diverse genotypes of onion. It was observed for all the traits that the phenotypic coefficient of variance was higher than the genotypic coefficient of variance. Those lines that performed better in yield and related attributes can be used for further breeding programs. Large variability and significant genetic variations were observed among the genotypes. Between the fresh and dry weight of the bulb, high genetic advance and heritability were observed. Dry weight of the bulb was correlated with the yield (Singh *et al*., 2014). The purpose of mutation breeding is to create genetic variations and develop significant correlations among the traits that the breeder can use to develop new verities. Research was conducted to improve morphological traits in onion, and the treatments were gamma radiations and sodium azide. Four doses of gamma radiations 2, 4, 6, and 8kR and three concentrations of 0.1, 0.3 and 0.5% sodium azide were applied. Results were very effective and showed that combining application of radiations and mutagen can create variability and improve morphological traits in onion (Sushama and A. K. 2017).

Genetic diversity

Diversity among the onion genotypes is due to bulb shape, weight, neck width, bitterness, dry skin color, and dry skin width, which is very high. To estimate diversity 14 red and 9 white onion genotypes were collected from different countries. A dendrogram was performed to estimate morphological similarities among the red and white onion genotypes. In red onion, 90.2% of variations were due to seven PC axes. In white onion, 96.4% variations were observed (BAGCI *et al*., 2022). *Allium cepa* L. is an economically significant crop and is cultivated throughout the world. But, very little research has been carried out on the crop for a few reasons, such as the biennial nature of the crop, sexual incompatibility, limited crosses, high heterozygosity, and large genome size. Under the changing climatic conditions, it is very important to create genetic variations, and induced mutagenesis is the best method that can be used to develop new cultivars with high adoptability. New cultivars can show tolerance against biotic and abiotic stresses. Variations are very important for selecting the best genotype to get maximum yield. Induced mutation breeding produces mutants with heritable genetic variations. These variations can be created through chemical (mutagens) and physical methods (Singh *et al*., 2021).

Gene, molecular genetics, markers

The prime objective is to increase the yield, which has been increased through heterosis by introducing cytoplasmic male sterility (Jones and H. 1936). The development of pollens is an energy-consuming process so that CMS energy can be reserved, and mitochondrial genes are involved (Chen *et al*., 2014). Henry A. Jones (father of hybrid onion) was the first person who developed the source of CMS in onion in 1952. Berninger discovered the second source of CMS (Berninger and E., 1965). Because of stable cytoplasmic male sterility, S-cytoplasm is used by the growers because of no reduction in female fertility because of nuclear level recessive alleles (*ms*) and for restoring male fertility (*Ms*) (Havey *et al*., 1994). For the development of CMS, conventional breeding takes 4-8 years, but molecular markers can save time. Markers that distinguish mitotypes have been developed in onion (Kim and S., 2014). A molecular marker based on *cob* mitochondrial and chimeric genes has been developed (Sato and Y., 1998). Other markers that distinguish the three types of cytoplasm based on DNA sequence have been developed: *cox1* gene, c oxidase subunit I, and chimeric *orf725* gene (Kim *et al*., 2009). Recently, the Nuclear Male fertility restoration (*Ms*) locus and source of CMS have been discovered (Havey *et al*., 2021). Bulbing and flowering in onion are controlled by multiple genes (Baldwin *et al*., 2014; Lee *et al*., 2013; Taylor, Massiah, & Thomas, 2010). FT gene locus is responsible for bulbing and flowering in onion. Two antagonistic FT genes initiate bulb formation. AcFT1 is responsible for bulb formation, and AcFT4 inhabits bulb formation (Khokhar, 2017). For breeding programs, it is important to study genetic divergence and variability for the parent selection. For this purpose, a study was conducted among 20 onion genotypes for bulb quality and yield-related attributes. With 31 SSR markers, diversity was determined at a molecular level. Additive gene action was observed for the inheritance pattern of many traits. Genetic variability was observed among the genotypes. More than 87% of genetic diversity was due to seven PCs. The diameter of the bulb was between 3.5-4.5cm. Phenolic compounds were related first to PCs. 16 primers were amplified, which produced 32 alleles. Highest polymorphism was detected for six primers i.e AMS 16, gSSR 38, gSSR 39, gSSR 50, ACM 018, and eSSR 20, and lowest for primer ACM 004. MI was maximum for ACM 326 followed by ACM 018 (Raj *et al*., 2022).

16 RAPDs, 10 primers, and 10 ISSR, 6 primers were used to analyze genetic similarities and diversity among 10 onion cultivars. Plumule length, germination percentage, seedling length, and root length differed among the cultivars. RAPDS showed 52, and ISSR showed 28 polymorphic band patterns (Sudha *et al*., 2019).

genome editing

Onion is a monocotyledonous crop, but successful *Agrobacterium*-mediated transformation has been reported (Dommisse *et al*., 1990; Eady *et al*., 2000). Cells that show low yellow auto-inflorescence are more suitable than those with high auto-inflorescence for *Agrobacterium*-mediated transformation (Kamata *et al*., 2011). Herbicide resistance gene has been successfully transferred in onion, and an anti-sense has been constructed to lower the tearing effect (Eady *et al*., 2008). But no such product has been released commercially because of consumer diffidence and high cost. To avoid a long time for the development and commercialization of new onion cultivars new technologies such as CRISPR/Cas (Schiml *et al*. 2014) can be helpful to incorporate traits of high economic importance and nutritional value into the existing onion cultivars.

Success stories in the world, especially in Pakistan

Double haploids have been developed in onion genomic research. They are used to identify genes and other regions in the genome that affect the quality traits like color, fructan, bolting, and restorer of male sterility. Through in vitro gynogenesis haploid production is only possible in onion and it is influenced by genotype, climatic condition, growth stage, cultural conditions and physiological stage etc. to induce haloid production pollination through irradiated pollens have been found very effective. Whole flower bud culture is an appropriate method for haploid production. Limiting factor after haploid production is chromosome doubling for double haploid production. For gynogenic haploid extraction, Onion Haploid OH-1 released by USDA can be used (Khar *et al*., 2019). Gene transfer in onion remained a problem for some time. Gene transfer can be possible through genetic transformation somatic and sexual hybridization. Sexual hybridization is a widely used method for the induction of genetic variations. If somehow sexual propagation is not possible, then somatic hybridization and genetic transformation provide a way to create genetic variations. Through somatic hybridization, cytoplasmic male sterility has been transferred in onion through leek, and it is also used to fill the gap between onion and garlic. Recently genetic transformation through *Agro bacterium* and biolistic gene transfer has been developed in onion, garlic, and shallot. Transgenic *Allium* plants are available *bar* or ALS gene for herbicide resistance, for insect resistance *Bt* gene and for milder taste antisense alliinase genes are known. Transgenic onions were fertile, have normal phenotypes, and have the same polidy level and transfer gene in Mendelian fashion (Zheng *et al*., 2008).

Interspecific hybridization is the best method for transferring the resistance gene to overcome the plant protection agents and protect the onion from diseases, pests, and abiotic stresses. Transferring other metabolites and odor molecules that benefit human health is also essential. It increases genetic diversity and is also helpful for improvement of *Allium* crops. In the present situation, wild relatives can transfer resistance genes, and *Allium*has untapped gene pool (Benke *et al*., 2021). If we become successful in developing new high-yielding and resistant ver

To get maximum yield, there is a need to cultivate recommended varieties, appropriate crop water requirements, management of plant population density, plant nutrients, insects, and diseases (Habtamu, 2017). There is a need to identify genes responsible for haploid induction, develop techniques for chromosome doubling effectively, gynogenic responsive genes, and a methodology to transfer genes from one genotype to the desired genotype (Khar *et al*., 2019)**.**

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Declaration

Conflict of interest

The researchers affirm that there were no financial or commercial ties that might be seen as a potential conflict of interest throughout the research's execution.

Data Availability statement

All data generated or analyzed during the study have been included in the manuscript.

Ethics approval and consent to participate

These aspects are not applicable in this research.

Consent for publication

Not applicable

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