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Review Article

The significance of the faba bean dwarfism against the backdrop of climate change

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Abstract

Climate change is the term used to describe changes in climate over time. It has become a global problem, which requires urgent intervention. Sudden temperature and precipitation changes cause an increase in diseases and pests seen in agricultural production while decreasing plant yield and quality. Hence, it is inevitable for people to face famine because of declining global agricultural production. Faba bean (Vicia faba L.) is one of the critical plants to overcome these problems due to its nutritional and environmental aspects. It has rich nutritional value, able to protect soil and the environment. To boost the yield of faba bean, it is important to consider gibberellic acid, a plant hormone that regulates plant growth. In its deficiency, the stem size remains short, causing dwarfism. While the stem size decreases, the number of seeds obtained on a stem increases. Mainly, dwarfism causes an increase in the yield of the plant and harvest index. To increase the yield of the faba bean, it is expected that the plant will be subject to scientific examination in all aspects. However, scientific studies on the dwarf gene have remained limited. Therefore, this review examines the dwarfism of the faba bean in terms of yield and harvest index.

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Introduction

Climate change is a broad term that refers to both local and global scale changes (Pachauri et al., 2014).These changes have far-reaching consequences for both human and ecological systems (IPCC, 2014).Climate change reduces agricultural production yields (Wolfe, 2013). It also has an impact on food security; the number of people suffering from hunger worldwide has been increasing since 2014 (Raj et al., 2022).

To combat global warming and food security, it is important to obtain high-yielding plant varieties. In this scope faba bean (*Vicia faba L.*) takes a crucial place in terms of being both animal and human nutrition and a functional food source with its rich nutritional value (Dhull et al., 2022). Therewithal, its contribution to maintaining the sustainability of agricultural systems is important (O'Donovan et al., 2014).

Objectives

This study will discuss the significance of the faba bean and give details about its' production amounts globally. Many studies carried out on the dwarf gene, which increases the plant yield in different plant groups since the green revolution. In contrast, dwarfism studies are limited to the faba bean. Diverse points of view are critical in assisting broad bean plant breeders in developing new, high-yielding cultivars. It will emphasise the role of the dwarf gene in enhancing plant yield elements, which has expected to become more essential because of climate change.

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Global Faba Bean Production

Faba bean is one of the earliest domesticated plants globally (Singh et al., 2013). It belongs to Leguminosae (Fabaceae) family with 19,400 species and 740 genera the third-largest family among other plant groups (Lewis et al., 2005; Abuzayed, 2019).Plant cultivation has begun in the Early Neolithic Period (8000 BC) (Cubero 1974). However, there is not any precise information available regarding the plant's wild ancestors (Abuzayed, 2019).

Faba bean is the most important legume crop widely grown worldwide. It is quite adaptable. It can be grown on high saline, clay soils in temperate, tropical, and subtropical regions (Brink et al., 2006).The quantity of production ranks fourth after chickpeas, lentils and peas (FAO, 2021). Previously, similar data shown by (Akibode et al., 2012) (Figure 1).

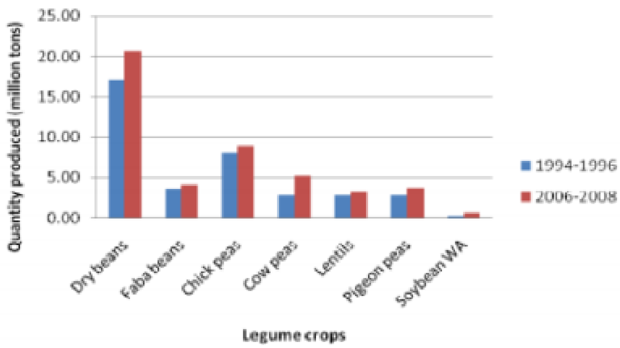

Figure 1. The global legume crops production amounts (Akibode et al., 2012)

In 2019, the global area under legume crop cultivation is 2.6 million hectares, with a production of 2.1 tonnes per hectare. China leads the way with 873 thousand hectares (38%) of cultivation area (Watts et al., 2011). FollowingEthiopia (19%) andMorocco (7%), respectively, produce the most (Akibode et al., 2012).It is grown 39.3 % in Asia, 28.1 and 20.5 percent in Africaand Europe respectively (FAO,2018).

Khazae, (2014) claimed that although faba bean production decreased from 1961 to 2012, yield per area of cultivation grew from 0.9 tons/ha to 1.86 tons/ha (Figure 2). This is unavoidable that is the outcome of advancements in plant breeding technologies (Bond et al. 1994; Khazaei, 2014).

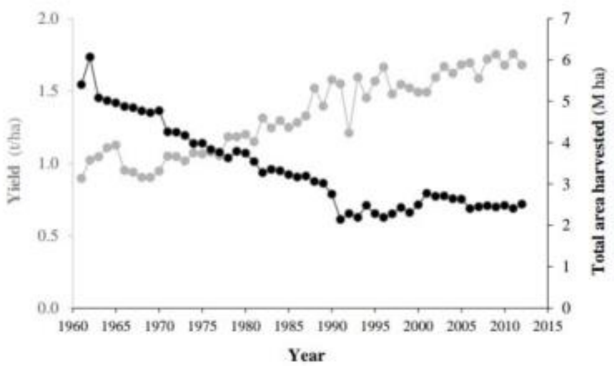

Figure 2. Faba bean harvested area and yield changes (1961-2012) (Khazaei, 2014)

The importance of the Faba Bean

Faba bean cultivation is valuable for many reasons.It is crucial as a human nutrition and functional food source with its rich nutritional value, that is, high in K, Ca, Mg, Fe and Zn, balanced amino acid profile, and high protein content (20% to 41%) (Dhull et al., 2022). Also includes bioactive compounds of polyphenols, and carotenoids, carbohydrates (Karkanis et al., 2018) which makes the plant health-enchancing properties (Martineau-Côté et al., 2022).

Moreover, because of its capacity of fixing high amounts of nitrogen to the soil content, faba bean plays the key role in sustainable agriculture and the cultivated rotation (Jensen et al., 2010). Similarly, legumes have the ability to adapt to poor environments due to their nitrogen fixation property with Rhizobiaceae bacteria (Vance et al., 1998). Its contribution to maintaining the sustainability of agricultural systems is important, as it is highly efficient in the symbiotic fixation of atmospheric nitrogen. The cultivation of faba bean improves the soil structure and makes it sustainable (Khazaei, 2014).

Studies have shown that faba bean as a green manure provides an increase in yield in many plant groups (O'Donovan et al., 2014). Faba bean has a protective effect against the spread of diseases and increasing genetic diversity (Zang et al., 2019) as well as increasing the yield of plants (Mouradi et al., 2018 cited in Martineau-Côté et al.,2022) in land rotation and intercropping.

The Green Revolution & Dwarfism

The Green Revolution, also known as the Third Agricultural Revolution, encompasses new technologies to increase agricultural production and yield from 1943 to 1970 in Mexico (Ameen et al.,2017), and the widespread use of chemical fertilizers, pesticides, and controlled irrigation (Eliazer Nelson et al, 2019). William Gaud, director of the United States Agency for International Development (USAID), originally used the term "green revolution" in 1968. The main achievement of the green revolution is the discovery of more productive varieties. This was achieved by introducing the dwarf gene. Dwarfism, the number of seeds on a stem and the ability of the plant to use nitrogen fertilizer can increase, so the harvest index can be increased (Brazauskas et al., 2018).

The plants' agronomic qualities are enhanced (Hedden, 2003). These changes in agriculture include the incorporation of varieties different from the new traditional varieties of dwarf wheat and rice (Gaud, 1968). As a result, of these initiatives, higher yields have been achieved compared to the 1960s, and a productivity increase has been achieved in crop production against the need for overconsumption due to the increasing human population (Ameen et al., 2017).

Behind the revolution, dwarfism was a keystone. Thus it is important to mention gibberellic acid to explain the basis of dwarfism. Three gibberellins are formed gibberellic acid (C19H22O6), gibberellin A1 (C19H24O6), and gibberellin A2 (C19H26O6) (Brian, 1959). Gibberellin is a plant hormone that regulates plant growth (Rodrigues et al., 2012). The internode distance and stem elongation of the plant increase with the amount of gibberellic acid (Hughes et al., 2020). It stimulates the fruit production of the plant and root development. Additionally, it reduces or breaks the dormancy of seeds and tubers. In some plant shoots, it allows for cell expansion (Brian, 1959). In essence, the discovery of the gibberellin hormone has led to success in studies of changing the size of the plant stem (Rodrigues et al., 2012).

On the contrary, in the absence of gibberellic acid, if less is used, the plant body length remains short and dwarf plants occur. In tall plant species, as the height of the plant increases, it becomes more difficult to carry grain (Hedden, 2003). Therefore, dwarf plants carry more grain than tall plants.

History of Faba bean Dwarfism

Plant breeders have focused on dwarfism for many years since the green revolution (Mitchell et al., 2000). As mentioned above the studies mainly focused on rice and wheat, but later on, it was achieved to find dwarf mutations of legume crops (Hughes et al., 2020). Gibberellin insensitivity results from mutations in genes that are encoding gibberellin signal proteins (Peng et al., 1999; Hughes et al., 2020). According to researches carried out on the subject, there have been six studies conducted on the topic. First off, in a study by Bond in 1962, the dwarf gene, dw1 was discovered on the Compacta variety, and in a study by Sjödin in 1971, the dw2 gene, which was acquired by a spontaneous mutation, documented. The spontaneously generated dw3 gene was recorded in a study on the screening of the HG 115C line by INRA (Institut National de la Recherche Agronomique) (Hughes et al., 2020). The dw4 gene and the dw5 gene were obtained through mutagenesis utilising X-ray (Ward et al., 1986; Hughes et al., 2020) and MS (ethyl methane sulfonate), respectively. Genotype Rinrei, a dwarf and semi-dwarf mutant developed through y-ray irradiation, in 2004 (Fukuta et al., 2004; Hughes et al., 2020). O'Sullivan recently discovered that the Ethiopian bean terrestrial race IG 12658 had a lack of GA hormones (Hughes et al., 2020).

Educational and Awareness Perspective

The problem of climate change has become an increasingly important issue. Increasing awareness, environmental awareness and sensitivity to ecological issues are of vital importance to take precautions in this regard. Food production, and therefore its security, depends on climate change. Legumes, specifically Vicia faba L. with its high protein content, crucial for ensuring food safety. Moreover, legume crops reduce the demand for N fertiliser, produce fewer greenhouse gases, and allow for more carbon retention in soils (Monteoliva et al.,2023).

In this direction, it is vital for plant breeders to take every aspect of the plant and initiate any work that can increase its yield. Likewise, it is essential for academicans to carry out studies on this direction. Developing high yielding Faba bean varieties helps secure global food requirements.

Conclusion

Climate change has become a global problem that needs rapid policy development at the national and international levels. Therefore, in order to reduce the drawbacks of climate change, legumes take an important place in their nutritional content and equally important contribution to maintaining the sustainability of agricultural systems. In this regard, gibberellic acid should be considered, one of the plant growth hormones that cause changes in plant size with the stimulation effects of the plant from seed to flowering. Dwarf faba bean varieties with short stem lengths, high grain setting rate and therefore high yield are important for breeding studies. Moreover, dwarfism improves the plant's capability to use fertilizers more efficiently. Developing high-yield varieties is essential to the sustainability of agriculture and the food chain at all stages. In this direction, this review aims to provide information about to provide information on faba bean cultivation and its significance, and the dwarfism gene in this direction.

Recommendations

- Plant breeding studies should be more focused on dwarfism to get a higher harvest index in a worldwide
- The importance of faba bean production should not be neglected to combat the drawbacks of climate change
- Researchers should consider the effects of gibberellic acid on plant yield

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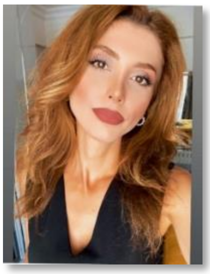

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