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# Effects of different soil management styles and cropping practices on the yield and quality of fava bean (*Vicia faba* L.)

Somayeh Karami*

Faculty of Agricultural Sciences and Natural Resources, University of Khuzestan
Mollasani, Khuzestan, Iran, Postal Code: 6341773637
*Corresponding author: sbadiei618@gmail.com

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## Abstract

This research aimed to determine the effects of various soil tillage techniques and the use of organic and chemical fertilizers on the overall yield and quality of fava beans. The study emphasized the significance of fertilizer types and their interaction with soil tillage methods. Although the quantity of grains per pod was notably influenced by the choice of fertilizers, the impact of soil tillage alone was found to be insignificant. Moreover, this study demonstrated that the yield index of fava beans was significantly influenced by fertilizer sources, emphasizing the importance of proper nitrogen managements. These findings provide valuable insights for enhancing crop production and quality through optimized soil tillage practices and the use of organic and chemical fertilizers. Through an examination of both the measurable and qualitative elements of fava bean cultivation, this study offers valuable knowledge on how to optimize the application of nitrogen fertilizers and effectively utilize mycorrhizal inoculation to improve grain yield and seed quality. These findings have implications for sustainable agriculture practices and guide farmers and researchers in making informed decisions regarding soil management strategies in fava bean cultivation.

## INTRODUCTION

Tilling considers as an indispensable component of industrial farming in modern agriculture. The objective behind tilling is to create an optimal environment that facilitates seed germination, fosters root system development, and controls weed growth. It also enhances soil porosity and permeability, improves soil structure and stability, ensures effective seed-soil contact, reduces physical resistance, buries plant residues, promotes the mixing of fertilizers and pesticides with soil, and disrupts earthworm tunnels, thus reducing evaporation rates, particularly in dry and semi-arid conditions (Titi El, 2010; Nguyen et al., 2018).

Tillage instigates significant alterations in soil conditions, aids in the decomposition of crop residues, and facilitates nutrient cycling within the soil (Mutegi et al., 2010). In contrast, no-tillage systems exhibit distinct temperature patterns compared to traditionally plowed soil, accompanied by increased surface density (Ognik et al., 2007). Consequently, these conditions lead to inadequate drainage and ventilation, resulting in a slower release of gases from the soil (Nguyen et al., 2018). Moreover, the no-tillage system retains a larger portion of crop residues when compared to conventional plowed soil. Since these residues are not thoroughly mixed with the soil and are less exposed to soil microorganisms, their susceptibility to decomposition is reduced.

The management of soil resources is a prominent subject in sustainable agriculture, focusing on the examination of soil organisms and their beneficial interactions within the ecosystem, such as food chains and vital cycles (Moreau et al., 2010; Modolo et al., 2018). In both natural and agricultural environments, plants and soil microorganisms share a mutual relationship

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that greatly influences various aspects, including soil structure, biological processes, nutrient chemistry, plant growth, and adaptation to environmental changes (Collins et al., 2003; Karami chame et al., 2016). Numerous studies have demonstrated that soil alterations like salinization or changes in electrical conductivity (EC) directly impact physiological processes, gene expression, and production quality in plants (Petersen et al., 2012; Pavlidis et al., 2018; Mirbakhsh and Sedeh., 2022; Mirbakhsh et al., 2023). Biological fertilizer, including natural entities, can be used as complementary or alternative options to chemical fertilizers in sustainable agriculture (Pingping et al, 2017). However, nano-fertilizer is used widely these days despite their environmental contamination due to their fine size, easy distribution, and inappropriate usage (Sharma et al., 2009; Fan et al., 2013; Vishwakarma et al., 2017; Khan et al., 2021; Mirbakhsh, 2023). Researchers have stated that mycorrhizal fungi have led to increased yield and yield components in corn, as these fungi possess abundant hyphae that penetrate plant roots, increase root weight, and enhance the absorption of phosphorus and water, thereby promoting yield components (Parsa Motlagh, 2011; Dotaniya et al., 2016).

Although soil tillage is known to improve crop yield, it can have adverse effects on the mycorrhizal network and hinder the growth of arbuscular mycorrhizal fungi in the plant's root zone. Soil tillage selectively affects mycorrhizal organisms, potentially disrupting their development and functioning (Dihazi et al., 2012; Egamberdieva et al., 2016).

The act of soil tillage brings about changes in the physical, chemical, and biological characteristics of the soil (Beauregard et al., 2010). Developing a mutual symbiotic association between plants and mycorrhizal fungi can greatly influence nutrient and water uptake, subsequently impacting grain formation. Phosphorus, an essential nutrient for plants, plays a crucial role in the development of flowers and seeds (Girolami et al., 2009; Großkinsky et al., 2016).

Mycorrhizal fungi require carbohydrates provided by the plant. It appears that after the initiation of symbiosis with the plant, mycorrhizal fungi obtain the necessary nutrients from the host plant while promoting the development of the plant's rhizosphere through mycelial branching and their own roots. Additionally, they produce the enzyme phosphatase, which makes non-absorbable soil phosphorus available to the plant, partially fulfilling the plant's phosphorus requirements, especially at lower soil phosphorus levels (Fathi and Oshtrinani, 2016). As a result of improved phosphorus utilization through symbiotic associations with mycorrhizal fungi, wheat plants experience better access to non-absorbable soil phosphorus, which can contribute to the weight and number of grains in the spike (Grover et al., 2011).

Researchers conducted a study to examine the impact of various soil tillage methods on plant function, soil performance, and yield components of soybeans. They found that the highest grain yield was achieved under a no-tillage system, which involved retaining residues. This was attributed to the increased weight of a thousand grains, resulting from enhanced soil moisture retention in this particular tillage system (Krell et al., 2011).

Furthermore, the study indicated that conservation tillage methods resulted in lower yields for wheat and maize compared to conventional soil tillage, with a decrease of around 10–14%. This reduction was attributed to a decline in soil nitrates in the conservation tillage method. However, when nitrogen levels were increased in the soil through elevated fertilizer consumption, no significant difference in performance was observed between conventional and conservation tillage methods (Mirsha et al., 2017).

This experiment aimed to determine the influence of various soil tillage methods and the combined application of organic and chemical fertilizers on both the quantity and quality aspects of fava bean (*Vicia fava* L.) performance, which served as our primary model species. Fava is now grown worldwide on 2.67 million ha in the year 2020. The total world production of fava bean is 5.67 million tons. Cultivation area for fava bean in Iran is 7,918 ha (FAO, 2022). One way to increase fava bean production and improve its quality is to use organic and biological fertilizers that can replace sources of phosphorus and nitrogen fertilizers.

## MATERIALS AND METHODS

### Field experiment

To assess the effects of different cultivation methods and the interactive influence of organic and chemical fertilizers on the yield and quality of experimental fava beans, a split-plot experiment was conducted. The experiment was arranged in a randomized complete block design with four replications, taking place in the late spring of 2019 in the Sarableh region of

Kermanshah, Iran. The experimental site is situated at a latitude of 33 degrees and 47 minutes north, a longitude of 46 degrees and 36 minutes east, and an elevation of 975 meters above sea level.

The main plots consisted of three levels of soil cultivation, including no tillage, conservation tillage, and conventional tillage. Within each main plot, there were four fertilizer levels as sub-plots, consisting of inoculation with 50% mycorrhiza + nitrogen, no mycorrhiza inoculation + 50% nitrogen, 100% mycorrhiza + nitrogen, and no inoculation with mycorrhiza + nitrogen.

**Soil preparation**

In order to determine the soil properties prior to the implementation of the experiment, sampling was carried out from a depth of zero to 30 centimeters, and the properties of the soil were tested. The records of the soil sample analysis at the experimental site are shown in Table 1. In the conventional soil tillage system, for preparation, the land was first deeply plowed (-25 to 20 centimeters) using a moldboard plow, and then two perpendicular discs were used to soften the clods to a depth of 10–15 centimeters. Finally, the land was leveled using a leveling chisel machine. After preparing the land, the row planter was used for seed planting. In the treatment without soil cultivation, a direct seeding machine was used, which sowed the seeds into the soil using the row planter without plowing the soil.

**Plant preparation**

In this experiment, the fava bean seeds (obtained from the Agricultural Research Center of Rasht Province) was used for cultivation. Mycorrhiza fertilizer (Genus mosseae Glomus obtained from Ferdowsi University of Tehran) was used as an inoculant during planting, which was a mixture of spores, soil, and separated root fragments. During seed planting, a quantity of 50 grams of mycorrhiza fungi, including roots, soil, and spores, were used (each gram of the fungi sample contains approximately 300 viable spores). Nitrogen fertilizer was also applied at the recommended rate of 100 kilograms per hectare using urea as the nitrogen source, and this was applied to each subplot before planting.

Each subplot consisted of 6 rows, 3 meters in length, with a spacing of 50 centimeters between the rows, a distance of 15 centimeters between plants within the row, a planting depth of 4 centimeters, and a spacing of 2 meters between the replicates. A non-planted row was left between the subplots, with a spacing of 50 centimeters. The dimensions of each subplot were selected as 3 x 3 meters. Irrigation water is ensured not to mix between subplots and replications.

**Yield content**

To assess the seed yield and yield components, the physiological maturity stage was identified, characterized by over 95% of the pods reaching maturity. From each subplot, a square meter of the central area was selected, excluding the side rows and a 50-centimeter margin from the beginning and end of the subplot to avoid any marginal effects. The soil from this selected area was carefully extracted by hand and transported to the laboratory.

During the harvesting process, 10 plants were individually chosen from each subplot. Various observations were made, including on the number of pods per plant, number of seeds per pod, weight of seeds per plant, and weight of 100 seeds. In addition, the protein percentage was determined using the Kjeldahl method (Jackson, 1964).

**Data analysis**

The data obtained from the experiment were analyzed using SAS statistical software version 9.1. To compare the means of the desired traits, the LSD (Least Significant Difference) test was employed at a significance level of 0.05.

**Table 1.** Physiological and chemical properties of the experimental field of fava bean

| Depth (cm) | Soil texture | pH | EC | Organic carbon (%) | Available N | Available phosphorus | Available K |
|---|---|---|---|---|---|---|---|
| 0–30 | Silt-loam | 7.8 | 1.02 | 1.2 | 12.01 | 9 | 0.57 |

## RESULTS AND DISCUSSION

### Seeds per pod

Based on the results of the analysis of variance, it was found that the fertilizer sources and the interaction between fertilizer sources and soil tillage had a significant effect on the number of pods per plant, with a significance level of 1%. However, the main effect of soil tillage alone did not show significance, as indicated in Table 2. The treatment involving no-tillage practices, along with 100% nitrogen fertilizer application and without mycorrhizal inoculation, yielded the highest number of grains per pod, with an average of 31.10 grains per pod. This was notably higher compared to the treatment with 50% nitrogen fertilizer application and without mycorrhizal inoculation, which had an average of 4.94 grains per pod (Table 2).

Additionally, in the interaction effect of conventional soil tillage system using 50% nitrogen fertilizer application and mycorrhizal inoculation, there was an average of 10 grains per pod (Table 2). The response of the number of grains per pod under consistent soil tillage conditions and without mycorrhizal inoculation only showed the highest amount with an increase in nitrogen consumption to 100%, indicating that the number of grains per pod is visually responsive to nitrogen availability and a decrease in nitrogen consumption due to a decrease in photosynthesis, and production of photosynthetic materials leads to a decrease in this trait. In other levels, it was observed that in conventional soil tillage with a 50% reduction in nitrogen, but with the use of mycorrhizal inoculation, this nitrogen deficiency was compensated to a significant extent due to the increased ability of fava bean roots to absorb nutrients.

### Seed weight

Based on the analysis of variance, the results showed that only the main effect of fertilizer sources was statistically significant at a significance level of 1%. However, the effects of soil tillage and the interaction between fertilizer sources and soil tillage were not statistically significant at any level, as shown in Table 2.

Regarding hundred-seed weight, the results indicated a significant effect of fertilizer sources. The treatment with 50% nitrogen fertilizer application, along with seed inoculation with mycorrhizal fungi, yielded the highest weight at 5.5 grams. This was higher than the treatment with 50% nitrogen fertilizer application without mycorrhizal inoculation, which had a weight of 4.6 grams, as depicted in Figure 1.

Mycorrhizal fungi play a role in increasing nutrient availability in the root zone, and in combination with 50% nitrogen fertilizer application, they enhance nutrient uptake and translocation towards the seed, resulting in an increase in hundred-seed weight in fava bean plants. Additionally, mycorrhizal fungi promote the production of hyphae in the root zone, leading to improved nutrient and water uptake. Previous studies have reported an increase in thousand-seed weight in various plants associated with mycorrhizal fungi (Ardakani et al., 2006; Taheri Oshtrinani and Fathi, 2016). The significant effect of nitrogen fertilizer on hundred-seed weight has also been emphasized. The increased transfer of photosynthetic materials from the source (leaf) to the sink (seed) could be a reason for the observed increase in seed weight. This results in higher dry matter production, leaf area, and heavier seeds with increased nitrogen consumption (Onega et al., 2008; Piccoli et al., 2011).

**Table 2.** Analysis of variance on the effects of tillage and nutrition on fava bean traits

| Source of variance (SOV) | df | Number of pods per plant | Number of seed per pods | 100 seeds weight | Seed yield | Biologic yield | Harvest Index (HI) | Seed yield | Protein yield | Protein function |
|---|---|---|---|---|---|---|---|---|---|---|
| Replication | 3 | 14.21 | 5.150 | 0.126 | 133.8 | 115007.3** | 0.0029 | 0.0042 | 0.115 | 5.34 |
| Tillage (T) | 2 | 32.93* | 0.563 | 0.009 | 444.6* | 225700.6** | 0.0008 | 0.0141 | 0.436 | 8.69 |
| Error Tillage | 6 | 4.98 | 0.765 | 0.216 | 76.0 | 5276.9 | 0.003 | 0.079 | 3.512 | 10.97 |
| Fertilizer (F) | 3 | 96.82** | 12.393* | 1.510** | 606.6** | 1408307.1** | 0.0449 | 0.1892 | 7.534* | 49.05** |
| T × F | 6 | 42.82* | 13.950** | 0.181 | 1562.5** | 37369.8** | 0.0140 | 0.518 | 20.07** | 63.09** |
| Error | 27 | 9.66 | 1.603 | 0.201 | 110.8 | 48981.9 | 0.008 | 0.0457 | 1.745 | 5.05 |

Remarks: *and** significant at 0.05 and 0.01 respectively.

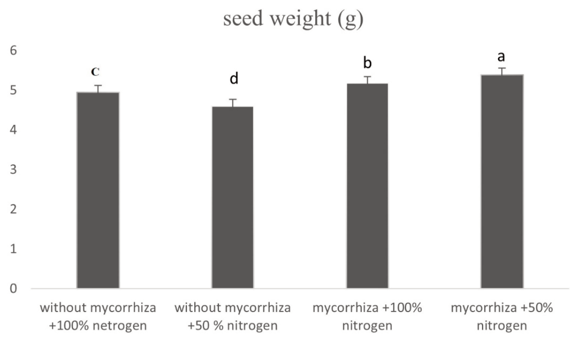


**Figure 1.** Effects of fertilizer source on the weight of fava bean seed

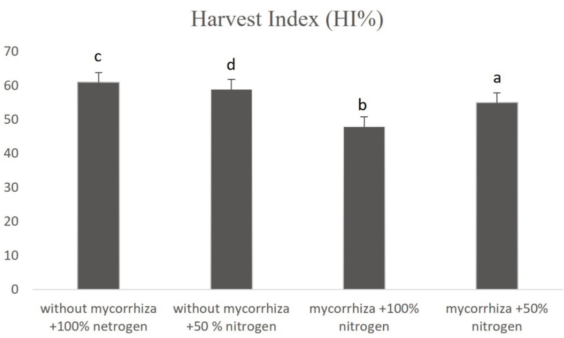


**Figure 2.** Effects of fertilizer source on harvest index (HI%) of fava bean

## Harvest index

The analysis of variance results revealed that the only statistically significant main effect on the yield index was attributed to the experimental treatment of fertilizer sources, with a significance level of 1%. Neither the soil treatment nor the interaction effect between fertilizer sources and soil treatment were statistically significant at any of the levels (Table 2). The treatment with 100% nitrogen fertilizer without seed inoculation with mycorrhiza resulted in the highest yield index, reaching 62%. This value was notably higher than the treatment with 100% nitrogen fertilizer combined with mycorrhiza inoculation, which yielded a yield index of 48% (Figure 2). It appears that increasing the nitrogen level has reduced the efficiency of mycorrhiza, as this increase has led to an improvement in performance. This result suggests that mycorrhiza activity requires an appropriate nitrogen level to effectively counteract nitrogen reduction effects. Overall, the yield index increased with the application of mycorrhiza and nitrogen, but there was a significant difference to 100% nitrogen. Researchers have stated that the main effect of chemical fertilizer on the yield index of fava bean is significant. Furthermore, other researchers have reported similar results in wheat (Alvarez et al., 2009; Kumar et al., 2012;).

## Seed-Nitrogen

The analysis of variance results indicated that both the main effect of fertilizer sources and the interaction effect between fertilizer sources and soil fertility were significant on seed nitrogen content, with a significance level of 1%. However, the effect of soil fertility alone did not show significance, as shown in Table 2. Comparing the means, it was observed that the treatment without soil fertility, combined with the application of 100% nitrogen fertilizer and without seed inoculation with mycorrhiza, had the highest seed nitrogen content at 3.01%. This value was higher than the conventional soil tillage treatment with 50% nitrogen fertilizer and without mycorrhiza inoculation, resulting in a value of 2.29%, as depicted in Figure 2. The increase in seed nitrogen content with an increase in chemical nitrogen fertilizer can be attributed to the availability of nitrogen to the plant. This suggests that higher amounts of chemical nitrogen fertilizer can lead to an enhancement in seed nitrogen content. Other researchers have also reported a significant interaction effect between soil fertility and chemical fertilizer on seed nitrogen content (Wasaya et al., 2017; Munoz-Romero et al., 2015).

### Seed protein

Based on the results obtained from this experiment, only the main effect of fertilizer sources and the interaction effect between fertilizer sources in soil fertility were statistically significant on seed protein yield (at a significance level of 1%). However, the main effect of soil fertility was not significant (Table 2). In terms of mean comparison, the protein yield in the treatment with conventional soil tillage along with 50% nitrogen fertilizer and mycorrhiza inoculation resulted in 24.99 kilograms per hectare.

It appears that in conventional soil tillage, protein yield increases with the use of nitrogen. Protein yield is a measure derived from the multiplication of seed protein content and seed yield, indicating that mycorrhiza utilization improves the growth and productivity conditions in fava bean plants. Researchers have stated in their study on corn that the effect of chemical nitrogen fertilizer, soil fertility, and their interaction had a significant impact on protein yield. (Wasaya et al., 2017; Rial-Lovera et al., 2016).

## CONCLUSIONS

The results of this study showed the significant effects of different practices such as fertilizer sources, soil tillage, and their interaction effect on various traits in fava bean plants. Mycorrhizal fungi improved nutrient availability, and the combination with reduced nitrogen fertilizer enhanced seed weight. Moreover, the yield index, which reflects overall plant productivity, was significantly affected by fertilizer sources and recorded the highest rate with 100% nitrogen fertilizer. However, the efficiency of mycorrhiza was reduced with increased nitrogen levels. Increasing chemical nitrogen fertilizer led to higher nitrogen content in the seeds, and seed protein yield was significantly affected by fertilizer sources and their interaction with soil tillage system.

In conclusion, this study highlights the significance of selecting appropriate fertilizer sources, with a particular focus on nitrogen, and recognizing the potential advantages of mycorrhizal inoculation in optimizing fava bean crop production. The findings offer valuable insights for farmers and agricultural professionals seeking to enhance various crop traits, including grain per pod, seed weight, yield index, seed nitrogen content, and seed protein yield in fava bean plants. By understanding the interactions among fertilizer sources, soil fertility, and mycorrhizal fungi, agricultural practices can be tailored to optimize crop productivity and nutrient composition, leading to improved outcomes in fava bean cultivation.

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