Effects of *Hedysarum coronarium* L. (sulla) as a Green Manure along with Nitrogen Fertilizer on Maize Production

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Abstract

Green manure as a source of soil organic matter is an important indicator of potential agricultural ecosystems capable of preventing erosion, reducing runoff, increasing soil permeability, improving ventilation, ameliorating the temperature, and enhancing the function of microorganisms. Therefore, to investigate the effects of green manure Sulla (*Hedysarum coronarium*) and nitrogen fertilizer on maize yield in Kermanshah, an experiment was carried out as split-plot in a randomized complete block design with 3 replications. The main factor was the use of Sula in two levels, namely application and non-application, while, the sub-factor was the application of N fertilizer at four levels of zero, 200, 400 and 500 kg/ha. The highest leaf area index was observed by 400 kg/ha N application along with green manure. Grains per ear determined using green manure and nitrogen fertilizer at levels of 0, 200, 400 and 500 kg/ha increased by 8, 10, 15, and 15%, respectively. The result showed that the Sulla green manure treatment increased the grain yield by 10% compared to the control treatment. Furthermore, the highest grain yield was obtained under two treatments of 400 and 500 kg N/ha which was significantly different from other levels of N applications. The application of green manure application also increased the maize protein content by 8% with a rise in the highest levels of nitrogen fertilizer. Meanwhile, the application of Sulla as a green fertilizer or pre-planting had a positive impact on increasing soil organic matter and maize yield. Therefore, cultivation of Sulla can be considered a positive task towards sustainable agriculture.

Keywords: Pre-plant cultivation; protein content; sulla; urea

INTRODUCTION

One of the most important factors associated with the development of agriculture and human food security is soil fertility maintenance. According to Talgre *et al.* (2010) and Soleymani & Shahrajabian (2017), the application of appropriate fertilizer is vital in increasing the quantity and quality of agricultural products. However, the need to intensify agricultural production has led to an increase in fertilizers and pesticide application, which has some adverse effects on the environment. Therefore, several studies have been carried out to determine methods that require less chemical use, such as green fertilizers. Green manure is a plant capable of producing biomass by creating live cover on the soil, preserving it from a variety of erosion before reaching the reproductive phase (Sainju *et al.,* 2007; Selvi and Kalpana, 2009). The cover crop is a generic term that encompasses a wide range of plants cultivated for various ecological reasons asides economic purposes. Green manure is one of the most important soil organic matter sources and an index for agricultural ecosystems potential for preventing crop erosion and runoff, increasing permeability, ventilation, temperature, and enhancing microorganisms function (Steenwerth and Belina, 2008). Cover crops are

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cultivated for a variety of reasons, including inhibiting land cover expansion by weeds, controlling soil-borne diseases, enriching soil through nitrogen fixation, improving its structure and organic matter, preventing nitrogen leaching, and sustaining the cropping system (Kruidhof *et al.,* 2008; Algan and Celen, 2011; Liebman *et al.,* 2012).

Sulla, (*Hedysarum coronarium*), is a two-year plant from the leguminous family also known as Halian, Spanish sainfoin, Sweet Vetch, and Honeysuckle French. It is adapted to semi-arid Mediterranean environments and is one of the multipurpose plants for controlling soil erosion, environmental protection, landscape beauty, forage, and honey production (Jerković *et al.,* 2010; Ruisi *et al.,* 2011). According to Ruisi *et al.* (2011), this plant is cultivated in Portugal, Spain, Italy, Greece, Morocco, Algeria and Tunisia with flowering days from 139 to 154 days. Ruisi further stated that the Sulla plant comprises of the runner and semi-runner ecotypes. In addition, its growth season tends to occur from late September to late June of the following year. Meanwhile, the early stages experienced slow growth until March with an increase in late June, due to the rise in air temperature. Similar to many grassland plants, the seeds also fall, and the plant starts summer dormancy (Sulas *et al.,* 2000). The sulla plant's root system is taproot with the branches on which the N fixing nodules are located. However, for nodule formation and nitrogen fixation, a particular breed of rhizobium called hedisari, which does not nodulate on any of the other species of the genus hedysarium is used (Córdoba *et al.,* 2013). According to Sulas et al. (2000), for areas cultivated with Sulla for the first time, the seeds need to be inoculated with these bacteria. Furthermore, due to its nitrogen-fixing ability, the plant can be cultivated as low-density green manure before main crops such as maize require a great deal of nitrogen. In addition to nitrogen fixation by legumes, a study carried out by Damon *et al.* (2014) reported that residuals of the leguminous family plants improved phosphorus nutrition in subsequent cereals. Although green manure application is important in nutrient supply and capable of enhancing soil properties, however, these plants are not able to provide the whole nutrient required by crops. Therefore, applying green manures with less chemical fertilizers increases soil organic matter and enhances its properties and crop yield production.

Nitrogen is an essential nutrient applied as fertilizer in most cropping systems to increase the biomass, grain yield, and components (Montemurro and Giorgio, 2005). Nitrogen fertilizer, especially in its inorganic form, tends to positively or negatively affect soil microbial biomass. Furthermore, the application of inorganic fertilizers under nutrient scarcity can have a stimulating effect on microbial growth. This is because the application of nitrogen fertilizer produces a higher volume of biomass. Therefore higher straw and residues are returned to the soil with an increase in carbon substrate (Treseder, 2008). Meanwhile, high concentrations of chemical fertilizers adversely affect the soil's physical and biological properties (He *et al.,* 2013), with lower nitrogen intake capable of reducing crop yields (Unkovich *et al.,* 2010). Therefore, it is necessary to balance the amount of nitrogen fertilizer application and plant residues in the soil by properly managing crop residues associated with its application, thereby improving productivity with a short term (Pandiaraj *et al.,* 2015).

Maize (*Zea mays* L.) is one of the four major cereals in the world and globally ranks third after wheat and rice. It is a staple food for a large human population in Latin America, Asia, Africa, and parts of Eastern Europe. According to Al-Kaisi & Yin (2003) and Soleymani *et al.* (2012), this crop is cultivated in Iran and many other countries due to multiple applications. In addition to humans, maize is one of the most important livestock nutrition sources due to its high sugar content, starch, and forage yield (Gholamhoseini *et al.,* 2013). There are very few studies on the cultivation effect of Sulla as green manure and its interaction with different levels of nitrogen on maize yield and its components. Therefore, this study aims to evaluate the yield and responsive traits of maize to Sulla green manure as well as the different levels of nitrogen fertilizer.

MATERIALS AND METHODS

In order to investigate the effectiveness of green manure (*Hedysarum coronarium*) and nitrogen fertilizer levels on maize yield and its components in Kermanshah, an experiment was carried out as split plot based using the randomized complete block design with 3 replications. The main factor, in two levels, was the application of Sulla and a non-application control system. The sub-factor was nitrogen fertilizer which was applied at four levels of zero, 200, 400, and 500 kg/ha. Furthermore, the amounts of nitrogen fertilizer obtained from the urea source were applied at three different times. Green manure cultivation was carried out in October 2015 and in March 2016. It was crushed and returned to the soil and mixed by rotator and disk before maize planting. One month after returning the green manure cover crop into the soil, the maize was planted in rows to achieve a density of 85,000 plants per hectare. The study site's soil properties were tested in two different times, before planting the Sulla green manure and before corn planting, as shown in Table 1.

Table 1. Soil properties before and after cultivation of Sulla as green manure

pH	EC	N %	P (ppm)	K (ppm)	OC %	
7.9	4.1	0.1	12.8	391.4	1.02	Before cultivation
8	2.1	0.16	34.3	589.1	1.59	After cultivation

The studied traits include plant height, leaf area index, yield components, grain yield and biomass, as well as grain protein content. The leaf area was measured and recorded using a Delta T model with the land area assigned to each plant (75 cm x 20 cm), and the leaf area index was calculated using Equation 1.

$$LAI = \frac{\text{Aall leaves}}{Aplant} \quad (1)$$

Where, LAI denotes leaf area index without dimension, $A_{all\ leaves}$ is total area of leaves per plant (cm^2) and A_{plant} is land area allocated to each plant (cm^2). In order to measure the percentage of protein in the seed, nitrogen value was first obtained by the Kjeldahl method and multiplied by conversion factor of 5.7% to estimate the grain protein content (Borghi *et al.,* 1995).

To calculate the final grain yield of the plants in the third and fourth rows, the first half-meter from both sides of the rows were removed, therefore, a total area of approximately 4.5 m^2 were harvested. The plants from each experimental plot were placed in separate sacks with six plants randomly selected from each sack to determine the number of grains per ear, which were further separated from the cob and stored at 70 °C in the oven for 72 hours. This produced to reach 0% grain moisture content with the grain yield calculated based on 14% moisture. One hundred seeds were counted and weighed using a seed counter, while the harvest index was calculated from the ratio of grain yield to total biomass.

Furthermore, analysis of variance was performed using the SAS 9.4 software, while the mean comparison was determined using Duncan's multiple range test.

RESULTS AND DISCUSSION

Plant Height

Analysis of variance indicated that the effects of green manure and nitrogen fertilizer on plant height were significant, as shown in Table 2. Means

Table 2**.** ANOVA analysis of some of Sulla properties in response to green manure and different levels of nitrogen

S.O.V	df	Plant height	Leaf area index	100-seeds weight	Number of seed per ear	Grain yield	Biological yield	Harvest index	Seed protein content
Replication (R)	2	44.04	0.100	2.62	123.17	99827.8	5721554.5	23.02**	1.89*
Green manure (Sulla) (G)	2	2281.50**	2.542*	273.44**	12973.5**	5818887.8**	237545.4	100.86**	3.62**
Error	4	142.88	0.023	1.34	171.5	257195.3	4567232.7	4.84	0.25
Nitrogen fertilizer (N)	1	474.94*	2.225**	164.78**	12648.44**	38492731.6**	168920503.1**	23.29**	2.37**
G × N	2	135.61	1.141*	7.54*	596.61*	2047.2	5331304.9*	8.95*	0.13
Error	12	83.74	0.327	2.09	120.28	190251.6	1473000	2.31	0.30
CV (%)		5.46	12.42	4.55	3.15	4.26	4.80	3.76	5.49

** and *: significant in 1% and 5% level, respectively comparison showed that application of Sulla green manure increased plant height by 12% (Table 3). Furthermore, plant height also increased with a rise in N fertilizer application. The highest plant height was observed in 400 kg ha^{-1} nitrogen treatment, which was not statistically different from 500 kg ha^{-1} treatment, as shown in Table 3. Returning the green manure plants back into the soil not only increases the available phosphate and nitrogen rather it also enhances organic matter, and improves physical, chemical and biological properties of soil, thereby leading to higher nutrient uptake and crop growth. The increase in maize plant height in the presence of the residue of Sulla is due to the abundance of nutrients released from its residues.

Due to the important role of nitrogen in plants growth and development, it is quite sensible to determine its positive effect on plants height. According to Hussain *et al.* (2006), increased levels of nitrogen fertilizer showed the greatest effect on plant height. The increase in plant height is attributed to the rise in the number and length of internodes (Somasegaran and Hoben, 2012). Khan *et al.* (2011) reported that wheat crops showed higher heights due to the application of nitrogen which provided more nutrients to the plants and enhanced soil water.

Leaf area index

Analysis of variance showed that the effects of green manure and nitrogen fertilizer on leaf area index were significant (Table 2). Comparison of means and interaction effects of green manure and nitrogen fertilizer showed that leaf area index was higher in green manure treatment than control (no green manure application) as shown in Figure 1.

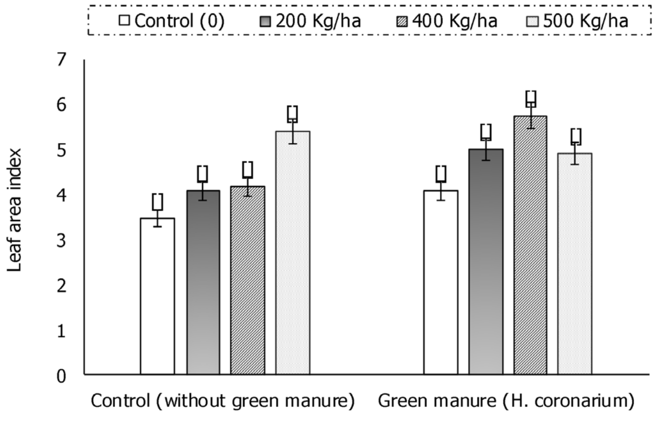

Figure 1. Means comparison of interactive effects of Sulla green manure and nitrogen fertilizer on leaf area index

Overall, the leaf area index increased with a rise in nitrogen fertilizer application, however, no increment was observed when 500 kg ha^{-1} of the fertilizer was applied along with Sulla green manure as shown in Figure 1. The highest leaf area index was observed in the application of 400 kg/ha nitrogen fertilizer, while the use of green manure with 500 kg/ha nitrogen fertilizer indicated no significant difference, as shown in Figure 1. Chutichudet Benjawan and Kaewsit (2007) reported the positive effect of green manure application on leaf area index. In addition, Eltelib *et al.* (2006) and Onasanya *et al.* (2009) also reported an increase in maize leaf area index due to nitrogen application. According to Ercoli *et al.* (2008), these increases are due to the direct effect of nitrogen on the expansion of the canopy cover,

Table 3. The simple effects of Sulla green manure and different levels of nitrogen on some maize properties

Treatment	Plant height (cm)	Seed protein content (%)	Grain yield (Kg/ha)
Green manure levels			
Control (without green manure)	157.7 b	9.64 b	9754.7 b
Green manure (H. *coronarium*)	177.2 a	10.41 a	10739.5 a
N fertilizer levels			
Control (0)	156.7 c	9.32 c	6663.7 c
200 Kg/ha	163.7 bc	9.76 bc	10268.5 b
400 Kg/ha	175.83 a	10.25 ab	11853.8 a
500 Kg/ha	173.5 a	10.78 a	12202.5 a

* Means with same letter(s) for each component are not significantly different based on Duncan test at 5% probability level.

which consequently led to a rise in solar radiation's absorbance. The factors affecting leaf area and plant canopy development in maize are Soil fertility, genotype, plant density and climate. Patel *et al.* (2006) stated that the high leaf area index is due to nitrogen application, which positively affects leaf size and life span.

Hundred Grain Weight

Analysis of variance showed that the effects of green manure and nitrogen fertilizer on hundred-grain weight were significant (Table 2). Furthermore, by comparing the means and interaction of green manure with nitrogen, an average hundred grain weight of 24% higher in green manure than the control treatment (no green manure application) was obtained.

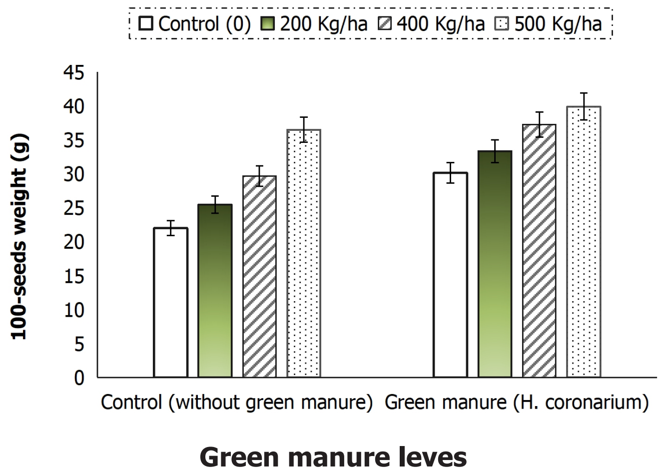

Figure 2. Means comparison of the effect of Sulla green manure and nitrogen fertilizer on hundred-grain weight

Hundred-grain weights also increased with a rise in the application of nitrogen, however this was different between application and non-application of green manure. In green manure treatment, the application of 200, 400 and 500 kg/ha nitrogen fertilizer, increased hundred-grain weight by 16, 35 and 66%, respectively, compared to control (zero kg). Meanwhile, in the treatment of Sulla green manure application, the increase was 11, 24 and 32%, respectively, as shown in Figure 2. The highest hundred-grain weight was observed in joint application of Sulla green manure and 500 kg/ha nitrogen fertilizer by enabling variation in essential plant nutrient sources and increasing maize uptake capacity, as shown inFigure 2. One thousand grain weight of maize which depends on the availability of photosynthetic materials during the filling period, replace or provide nutrients in the soil, promote fertility, increase organic matter, retain water, reduce evaporation, stimulate, increase and translocate photosynthetic materials to grains (Blanco-Canqui and Lal, 2009). Application of green manure application and chemical fertilizer leads to the gradual release of nutrients which in turn increases the grain weight and crop yield (Fageria, 2007). Bahrani (2015) stated that increasing nitrogen levels led to more redistribution of photosynthetic materials and higher grain weight.

Number of Grains Per Ear

Analysis of variance showed that the effects of Sulla green manure and nitrogen fertilizer, and their interaction on the number of kernels per ear were significant (Table 2). Interaction of green manure and nitrogen fertilizer on a number of grains per ear is shown in Figure 3.

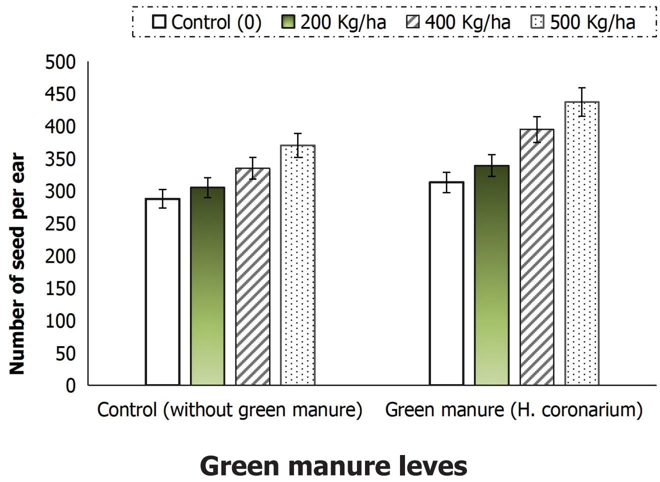

Figure 3. Means comparison of the effect of Sulla green manure and nitrogen fertilizer on grain number per ear

The application of green manure increased the number of grains per ear however, this rise was not similar at different levels of nitrogen fertilizer. Furthermore, the application of green manure at nitrogen fertilizer levels of 0, 200, 400 and 500 kg/ha, increased the number of grains per ear by 8, 10, 15 and 15%, respectively. Increase in the amount of nitrogen also led to a rise in the number of grains per ear compared to none nitrogen application. The highest increase (39%) was observed in 500 kg/ha nitrogen fertilizer treatment with green manure with the number of grains per ear shown in Figure 3.

Furthermore, the increase in the number of grains per ear is due to green manure, which enhanced soil fertility and availability of nutrients. The number of grains per ear is one of the important components of grain yield affected by the plant's nutritional status. Therefore, the availability of nutrients, especially nitrogen improves the soil physical and chemical properties, thereby improving the crop pollination conditions. Therefore, improved pollination leads to a higher number of grains per ear. According to Rieger *et al.* (2008), the adequate availability of nutrients in soil improves plants growth and increases photosynthates' conversion to dry matter, thereby leading to higher fertile spikes in wheat.

Grain Yield

Analysis of variance showed that the effects of green manure and nitrogen fertilizer on grain yield were significant (Table 2). According to the means comparison results, the Sulla green manure increased yield up to 10% more than the control treatment, as shown in Table 3. Other studies also reported an increase in maize grain yield due to the application of green manure (Cherr *et al.,* 2006; Tejada *et al.,* 2008; Tao *et al.,* 2017). The superiority of maize grain yield in Sulla green manure treatment over the control was because of the evaporation losses from the soil surface and moisture retention for a longer period. It was also due to the warm air and high evaporation from the soil during the maize growing season. Several studies have reported an increase in maize grain yield with a rise in soil moisture retention due to the residues (Limon-Ortega *et al.,* 2008). The impact of green fertilizers on maize is due to changes in soil microbial population and properties. Tao *et al.* (2017), stated that green manure's application changed the physicochemical properties of soil and its bacteria population in terms of order and sex. This is because plant root exudates have selective effects on soil microbial populations (Hartmann *et al.,* 2009). The application of green manure, soil acidity, organic matter and change in trace elements (Table 1) in this experiment, is consistent with the results of other studies (Coolon *et al.,* 2013; Tao *et al.,* 2017). The use of legume plants such as Sulla with nitrogen fixation potential increases its availability in plants (Chen *et al.,* 2014). Potassium also plays a role in increasing plant resistance to environmental stresses with the decomposition of soil organic matter dependent on factors such as temperature, soil moisture, acidity and fertility (García-Fraile *et al.,* 2016). Therefore, in applying green manure, the availability of nitrogen is effective in improving maize yield. Belachew and Abera (2011) stated that the cultivation of legumes as green manure increased wheat grain yield with a rise in available nutrients and soil organic matter. Larsen *et al.* (2014) reported that maize yield significantly increased after cultivating green manure and returning them into the soil compared to the conventional tillage conditions. They attributed to an increase in the destruction of the hard soil layer by plant roots and improved its conditioning and maize growth. The ratio of carbon to nitrogen in soil residues is one of the critical factors in determining green manure's effectiveness.

Application of green manure increased the phosphorus mobility in the soil and the availability of phosphorus which in turn led to a rise in the number of grains and ultimately increased the final yield. Surekha *et al.* (2006) stated that the simultaneous application of rice straw and legume increased soil nitrogen, its yield and components. These studies attributed legume plants' presence to rotation by increasing the activity of rhizobia and phosphate solubilizing bacteria and optimizing phosphorus uptake. Generally, the increase in maize grain yield due to the cultivation of green manure plants was dependent on several factors, including reducing soil evaporation and maintaining appropriate and accessible moisture because of residual cover, optimal use of water by crop, increasing the availability of nutrients, preventing weed growth, improving soil quality, maintaining nutrient balance, enhancing the growth of microorganisms, providing nutrients and preventing leaching.

Table 3 showed that an increase in nitrogen fertilizer application led to a rise in maize grain yield. The means comparison showed a significant difference between the nitrogen treatment and control. In terms of grain yield, nitrogen treatment levels of 400 and 500 kg N ha^{-1} failed to show a significant difference, thereby producing the highest yield (Table 3). Addition of nitrogen fertilizer increased corn yield insignificantly to some extent, therefore its role cannot be ignored (Kogbe and Adediran, 2003). Several studies have shown that the application of nitrogen fertilizer up to 455 kg/ha under different tillage systems increased grain yield, while biomass and nitrogen uptake of maize led to a rise in the economic yield levels (Torbert *et al.,* 2001). There are numerous reports on the positive effect of nitrogen fertilizer application on maize grain yield (Iqbal *et al.,* 2009; Khan *et al.,* 2011). For instance, the research carried out by Hokmalipour and Darbandi (2011) showed that nitrogen fertilizer had a positive effect on the yield and physiological properties of different maize cultivars. They further stated that the highest maize yield occurs at high levels of nitrogen. The results of other experiments also showed that the application of nitrogen fertilizer increased the vegetative and reproductive performance of maize crop compared to non-fertilizer treatment. Most of the studies attributed to this increase were mainly due to residues' effect on soil temperature and soil organic matter content (Vetsch and Randall, 2004). The use of nitrogen fertilizer is essential for the rapid growth of maize using maximum environmental resources and greater water/nutrient absorption used to enhance grain yield (Niehues *et al.,* 2004). Increasing maize grain yield due to rise in nitrogen fertilizer application is justified by increasing soil nitrogen, leaf area as well as light absorption and utilization efficiency, thereby leading to a rise in crop growth rate and yield (Kogbe and Adediran, 2003). Zotarelli *et al.* (2009) stated that maize crop production was higher under treatments of green manure crops (flower vetch, rye) with lower nitrogen fertilizer application levels compared to no-green manure crops with high levels.

Biological Yield

Analysis of variance showed that the effects of nitrogen fertilizer as well as the interaction between green manure and nitrogen fertilizer on biological yield were significant (Table 2). Comparison of means showed that biological yield in response to different amounts of nitrogen fertilizer with or without green manure was different. Although nitrogen fertilizer application increased biological yield in comparison with the non-nitrogen fertilizer application, the rise was more significant without Sulla treatment, as shown in Figure 4.

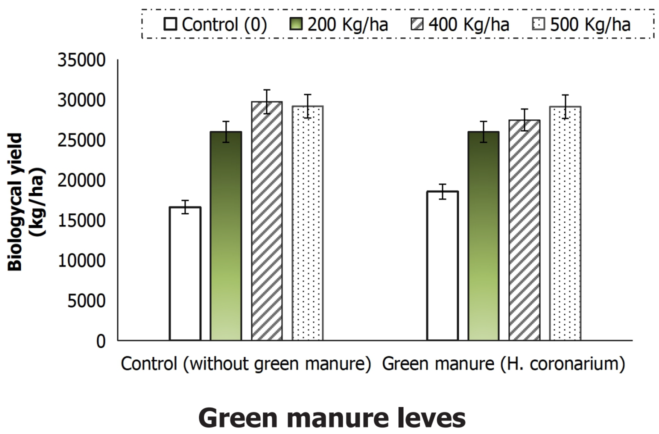

Figure 4. Means comparison of the interactive effect of Sulla green manure and nitrogen fertilizer on biological yield

Applying green manure along with nitrogen fertilizer treatments of 0, 200, 400, and 500 kg/ha increased biological yield by 10%, and reduced it by 1.5%, 10%, and 6.5%, respectively, as shown in Figure 4. The highest biological yield was obtained by applying 400 kg N fertilizer without green manure. Furthermore, the rise in nitrogen utilization when using green manure did not have a significant positive effect on biological yield with most of the nitrogen leached out of the roots access. According to Chen *et al.* (2014), plants receive 70 to 80 percent of their required nitrogen during vegetative development, with only a small portion used at the seedling stage. Therefore, the gradual uptake of nitrogen during vegetative growth is important for biomass production. Nemeikšienė *et al.* (2011) stated that using legumes as green manure increased the biomass of wheat by improving the soil's organic nitrogen content. This is because the low carbon to nitrogen ratio and the legume family's green manure plants tend to decompose more rapidly and release nutrients to the next crop in the rotation sooner than green lignin-containing fertilizers with high carbon to nitrogen ratios (N'Dayegamiye and Tran, 2011). According to several studies, inorganic fertilizers under nutrient scarcity have a stimulating effect on microbial growth. Therefore, the application of nitrogen fertilizer produces a higher volume of plants' biomass with the ability to provide more energy for the soil microbial population when their straw and residues returned back into the soil (Treseder, 2008; Spedding *et al.,* 2004). However, high concentration of fertilizers reduces soil microbial biomass. Several studies reported that increase in soil nitrogen content leads to a rise in vegetative organs production, while leaf area index and ultimately increases the occurrence of photosynthesis and dry matter production (Dordas and Sioulas, 2008).

Harvest Index

Analysis of variance showed the significant effects of the interaction between green manure and nitrogen fertilizer on harvest index. Comparing the means between green manure and nitrogen fertilizer showed an increase in their harvest index by 0, 4, 10, 16 and 8%, respectively (Figure 5). The highest harvest index was obtained from 400 kg N/ha treatment along with Sulla green manure application, as shown in Figure 5.

Harvest index shows the distribution ratio of dry matter production between vegetative organs and grains yield, which changes and impact on the final grain yield. In integrated systems, chemical fertilizers reduce the temporary lack of nitrogen availability during the early growth season till the green manure materials decomposed and provided the required nutrients. This study showed that the combination of chemical and green manure improved grain filling and harvest index. The fertilizer integration releases the nitrogen and other essential nutrients needed by the crop to improve photosynthesis and crop production slowly. Furthermore, the maize crop under this condition supports more photosynthates to grains and produces higher harvest index.

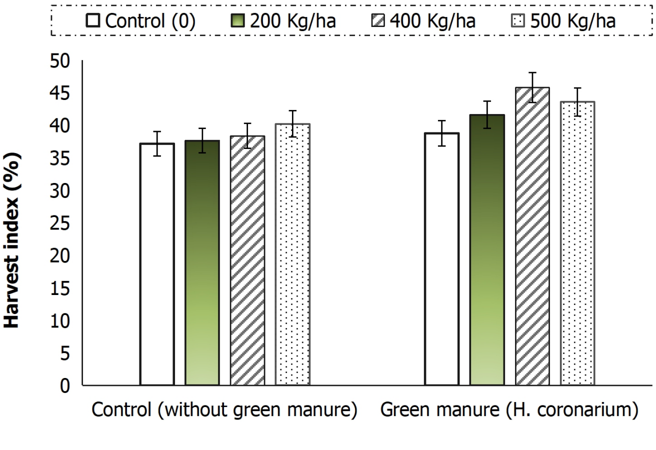

Figure 5. Means comparison of the interactive effect of Sulla green manure and nitrogen fertilizer on harvest index

Grain Protein Content

Analysis of variance showed that the effects of green manure and nitrogen fertilizer on grain protein content were significant (Table 2). The mean comparison showed that the application of green manure increased corn protein content by 8% (Table 3). The average effect of the application of nitrogen fertilizer showed that with increasing application, the percentage of grain protein also increased. The treatment of 500 kg/ha N fertilizer led to the highest (10%) grain protein, as shown in Table 3. Therefore, through a multi-year experiment, legumes' rotation was found as green manure with wheat crop and chemical fertilizer comprising of nitrogen uptake efficiency (Shah *et al.,* 2011). Furthermore, an increase in nitrogen uptake leads to a rise in grain protein because it is a major protein structure element. Abdelhamid *et al.* (2004) stated that canola residues significantly increased pod protein of faba bean. Ghuman and Sur (2001) also reported an increase in maize grain yield and its quality in the tillage reduction system by maintaining plant residues in the soil. In addition, various studies also reported that nitrogen fertilizer application increased the amount of nitrogen imported from vegetable parts to seed was more than carbohydrates, thereby leading to a rise in the nitrogen concentration and protein percentage (Sharma *et al.,* 2003). These results are similar to those of other studies which reported that an increase in the application of nitrogen fertilizer, leads to a rise in grain protein concentration increased (Guarda *et al.,* 2004; Garrido-Lestache *et al.,* 2005; Iqbal *et al.,* 2005; Subedi *et al.,* 2007). Furthermore, an increase in the percentage of maize grains protein with rising levels of nitrogen fertilizer was reported by other studies (Lawrence *et al.,* 2008; Ryan *et al.,* 2008; Gheysari *et al.,* 2009; Gholamhoseini *et al.,* 2013).

CONCLUSION

In conclusion, the use of green manure as an organic fertilizer creates a more sustainable agricultural system. Furthermore, this research showed that the application of Sula green manure significantly increased the final yield, its components and protein content of maize grain. The Sulla plant has tap root system with branches on which the nodes are fixed, in addition to forage production, which has the potential for nitrogen fixation, decrease in weed population, increase in soil organic matter and erosion prevention. It also helps to improve the growth of the next plant in rotation. Therefore, the planting Sulla as green manure on maize crop is very beneficial. However, it is necessary to balance the vegetative residues of the green manure with the application of nitrogen fertilizer, in order to obtain maximum grain yield. Hence, choosing the right method of split, application time and type of nitrogen fertilizers, along with the right amount of green manure, eliminates the need for chemical fertilizer, while preventing environmental contamination and nitrate accumulation in plant organs. The results of this experiment showed that the application of 400 kg /ha of nitrogen fertilizer with green Sulla manure was suitable for maize cultivation. This is because, in addition to improving the quality and quantity of maize yield, it also contributes to sustainable agricultural development by reducing the use of nitrogen fertilizer, thereby enhancing soil's physical and biological properties.

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CONFLICT OF INTEREST

The authors stated that there is no conflict of interest.

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