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*Original Research Paper*

# Chemical and Biological Influences of some Preceded Winter Field Crops on Productivity of Intercropped three Maize Cultivars with Soybean

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**A two-year study was carried out at Sids Agricultural Experiments and Research Station, ARC, Beni – Sweif governorate, Egypt, during 2012/2013 and 2013/2014 to determine the possible allelopathic effects of the preceded berseem, sugar beet and wheat crops on productivity of intercropped three maize cultivars with soybean. Three local maize cultivars (S.C. 122, T.W.C. 310 and Giza 2) were grown in alternating ridges (2:2) with one local soybean cultivar (Giza 22) after three winter crops (berseem, sugar beet and wheat) as preceded crops. A split plot design with three replications was used. The results showed that berseem roots secreted biologically active chemical compounds which have a positive effect on growth and development of maize under intercropping culture. The preceding berseem appeared to be promising for maize productivity under intercropping culture. On the contrary, sugar beet and wheat residues had negative effects on maize productivity under intercropping culture. All the studied maize traits were increased after berseem cutting except number of ears/plant and number of rows/ear in comparison with those followed sugar beet or wheat. Maize cultivar S.C. 122 had the highest values of all the studied traits compared to the other maize cultivars. The interaction between the preceded winter crops and maize cultivars was significant for all the studied traits except number of ears/plant and number of rows/ear. Intercropping soybean with maize cultivar S.C. 122 that followed berseem produced 7.11 ton/ha of maize grains in addition to 1.74 ton/ha of soybean seeds were gained by intercropping.**

**Keywords:** Allelopathy, Preceded winter crops, Intercropping, Maize cultivars, Soybean.

## INTRODUCTION

A cropping system usually refers to a combination of crops in time and space, and hence intensive cropping system should be characterized by a high degree of soil fertility. However, sizeable amount of crop residues is produced in farms; it is becoming increasingly complex to recycle nutrients, even within cropping systems. Maize (*Zea mays* L.) is a strategic crop and it is used for human consumption, animal and poultry feeding and industrial purposes. Although the highest maize yield productivity depended on soil fertility, maize cultivar and nitrogen (N) fertilization (Ding *et al*., 2005), however, organic N fertilizers must be converted, or mineralized, by microbes to nitrate and ammonium (Moore *et al*., 2009). Accordingly, decline in crop yields in cropping systems in recent years has been attributed to allelopathic effects.

Allelopathy is an interference mechanism, in which live or dead plant materials release chemical substances, which inhibit or stimulate the associated plant growth (May and Ash, 1990). In this concern, Fore (2005) showed that maize following sugar beet can be reduced or prevented by careful selection of appropriate fields for maize production, hybrid selection and most importantly, executing a comprehensive fertility management plan. The larger genetic variability of the maize cultivar BRS Planalto did not improve its grain yield when compared to the hybrids in low management system. The hybrids were more productive and profitable than the open pollinated cultivar in medium management system (Sangoi *et al.*, 2006). Also, the presence of winter wheat residue above and below ground decreased chlorophyll content in maize

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leaves and plant height in the early stages of maize development (Kravchenko and Thelen, 2007). Accordingly, maize cultivars could be played an important role to reduce negative effects of allelopathy.

Consequently, there is a need to use all available sources of nutrients and bacteria to maintain the productivity and fertility at a required level. It is known that plant responses to nutrient availability and bacteria depend on the availability of other required resources. Certainly, legumes are noteworthy in that most of them have symbiotic N-fixing bacteria in structures called root nodules (Sanginga *et al*., 1996). So, legumes is a useful means to sustain organic matter content and thereby enhance the biological activity, improve soil fertility and increase nutrient availability (Giller *et al.*, 1997; Kumar and Goh, 2000 and Palm *et al*., 2001). It is one of the most important sources for supplying nutrients to the crop and for improving soil health.

Fortunately, growing soybean ([*Glycine max* (L.) Merr.] with maize on the same ridge (mixed pattern) promoted rhizobia growth in rhizosphere of maize root compared to those in rhizosphere of sole maize, meanwhile, productivity of maize plant was increased through modifying the light environment around maize plants that directly affected positively ear leaf indole acetic acid and N contents in 2:2 pattern (El-Shamy *et al.*, 2015). Therefore, the main objective of the present research to determine the possible allelopathic effects of the preceded berseem, sugar beet and wheat crops on productivity of intercropped three maize cultivars with soybean.

## MATERIALS AND METHODS

A two-year study was carried out at Sids Agricultural Experiments and Research Station, A.R.C., Beni – Sweif governorate (Lat. 29º 12' N, Long. 31º 01' E, 32 m a.s.l.), Egypt, during 2012/2013 and 2013/2014 seasons. Table (1) shows chemical analysis of the experimental soil field after berseem cutting, sugar beet and wheat harvest. The experimental soil texture was clay. Chemical analysis of the soil (0 – 30 cm); pH, E.C., $CaCO_3$, soluble cations and available N, available P and available K were analyzed by Water and Soil Research Institute, ARC.

Table (2) shows total counts of each of *Azotobacter* sp., *Rhizobia* sp., *Bacillus* sp. and phosphate dissolving bacteria after berseem cutting, sugar beet and wheat harvest. These analyses were performed in General Organization for Agricultural Equalization Fund, Agricultural Research Center, Giza, Egypt and Cairo University Research Park, Faculty of Agriculture, Cairo University, Giza, Egypt. Chemical analysis of the soil was determined using the methods described by Chapman and Pratt (1961).

This experiment included 9 treatments which were the combinations of berseem (*Trifolium alexandrinum*), sugar beet (*Beta vulgaris*) and wheat (*Triticum aestivum*) as preceding crops in the winter season and three maize (*Zea mays*) cultivars (S.C. 122, T.W.C. 310 and open pollinated cultivar Giza 2) under intercropping with soybean (*Glycine max*) in addition to sole crops as following crops in the summer season. Berseem variety (Giza 6), sugar beet variety (Misribal), wheat variety (Beni – Sweif 1), soybean variety (Giza 22) and maize cultivars (S.C. 122, T.W.C. 310 and open pollinated cultivar Giza 2) were used.

Berseem, sugar beet seeds and wheat grains were sown on the $2^{nd}$ and $9^{th}$ October at 2012 and 2013 winter seasons, respectively, meanwhile, soybean seeds and maize grains were sown on $23^{rd}$ and $28^{th}$ May at 2013 and 2014 summer seasons, respectively.

In the two growing seasons, berseem and soybean seeds were inoculated by *Rhizobium trifolii* and *Bradyrhizobium japonicum,* respectively, before seeding it and gum arabic (acacia gum) was used as a sticking agent. During the two winter seasons, wheat grains and berseem seeds were drilled at the rate of 166.6 and 59.5 kg per ha, respectively. Sugar beet seeds were grown on one side of the ridge (70 cm) and were distributed to one plant/hill spaced at 20 cm. In the two summer seasons, intercropping culture was two maize ridges alternating with two soybean ridges (2:2), maize grains were grown in one row of the ridge (70 cm) and were distributed to two plants/hill spaced at 40 cm (35700 plants/ha), meanwhile soybean seeds were drilled in two rows of the ridge (70 cm) and were thinned to two plants/hill spaced at 15 cm (190400 plants/ha). Sole maize was conducted by growing maize in one row of the ridge (70 cm) and was distributed to one plant/hill spaced at 30 cm (47600 plants/ha), meanwhile sole soybean was conducted by drilling the seeds in two rows of the ridge (70 cm) and were thinned to two plants spaced at 20 cm (285600 plants/ha). Sole crops were used to estimate the competitive relationships.

All the tested crops were grown in accordance with local agricultural practice. Water was supplied by furrow irrigation. Calcium super phosphate (15.5% $P_2O_5$) at a rate of 357 kg/ha and potassium sulfate (48.0% $K_2O$) at a rate of 119 kg/ha were applied during soil preparation in the two winter seasons. The previous rates were applied during soil preparation in the two summer seasons. Mineral nitrogen fertilizer rate was applied during different growth stages of all the tested crops as follows: 35.7 kg N/ha for berseem, 166.6 kg N/ha for sugar beet, 178.5 kg N/ha for wheat, 35.7 kg N/ha for soybean and 285.6 kg N/ha for maize.

A split plot distribution in randomized complete block design with three replications was used. The preceded winter crops were randomly assigned to the main plots, meanwhile maize cultivars were allotted in subplots. Each plot contained 12 ridges, each ridge was 3.0 m in length, 0.7 m in width and the plot area was 25.2 $m^2$.

### *The studied traits*

The traits of vegetative growth at 85 days of maize sowing recorded on five plants from each plot were plant dry weight (g) and ear leaf area ($cm^2$) was determined as leaf length x leaf width x 0.75 according to Francis *et al*. (1969). At harvest, the observations on traits, namely plant and ear heights (cm), number of ears/plant, ear length and diameter, number of rows/ear, ear weight (g), grains weight/ear (g), shelling (%) and grain yield/plant (g). Maize grain and soybean seed yields were recorded on the basis of experimental plot and expressed as ton per ha.

### *The statistical analysis*

Analysis of variance of the obtained results of each season was performed. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimental seasons was carried out. The measured variables were analyzed by ANOVA using MSTATC statistical package (Freed, 1991). Mean comparisons were performed using the least significant differences (L.S.D) test with a significance level of 5% (Gomez and Gomez, 1984).

**Table 1**. Chemical properties of experimental soil after harvest of wheat, berseem and sugar beet crops before growing soybean and maize cultivars in the summer season

| Contents \ Crop | | Wheat | | Berseem | | Sugar beet | |
|---|---|---|---|---|---|---|---|
| | | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 |
| pH | | 8.13 | 8.16 | 7.95 | 8.00 | 8.10 | 8.11 |
| E.C. (mm/cm) | | 0.31 | 0.36 | 0.60 | 0.65 | 0.45 | 0.48 |
| Soluble cations (ml/L) | $Ca^{+2}$ | 2.40 | 2.50 | 0.80 | 0.80 | 1.90 | 2.00 |
| | $Mg^{+2}$ | 0.40 | 0.60 | 0.80 | 0.90 | 0.60 | 0.85 |
| | $Na^{+}$ | 2.10 | 2.30 | 1.04 | 1.10 | 1.90 | 2.10 |
| Soluble anions (ml/L) | $Hco_3^{-}$ | 0.40 | 0.45 | 0.40 | 0.45 | 0.40 | 0.45 |
| | $Cl^{-}$ | 0.90 | 0.95 | 0.35 | 0.45 | 0.90 | 0.95 |
| | $So_4^{-2}$ | 2.54 | 2.64 | 3.81 | 3.97 | 2.81 | 2.93 |
| Major elements (ppm) | N | 10.00 | 10.00 | 20.00 | 25.00 | 10.00 | 15.00 |
| | P | 13.00 | 18.00 | 27.00 | 30.00 | 18.00 | 23.00 |
| | K | 264.00 | 272.00 | 336.00 | 344.00 | 294.00 | 303.00 |
| Minor elements (ppm) | Fe | 7.42 | 7.46 | 8.34 | 8.44 | 7.58 | 7.68 |
| | Cu | 2.04 | 2.08 | 2.10 | 2.20 | 2.08 | 2.10 |
| | Zn | 0.78 | 0.80 | 1.08 | 1.09 | 0.78 | 0.82 |
| | Mn | 13.84 | 13.92 | 14.16 | 14.22 | 13.94 | 14.00 |
| Ferulic acid content (µg/g soil) | | 19.8 | 20.4 | 7.2 | 7.8 | 16.4 | 17.2 |

**Table 2.** Microbial analysis of experimental soil after harvest of wheat, berseem and sugar beet crops before growing soybean and maize cultivars in the summer season

| Microbial Group | Wheat | Berseem | Sugar beet |
|---|---|---|---|
| Total *Azotobacter* (mpn) | $1.1 \times 10^{2}$ | $2.8 \times 10^{2}$ | $1.8 \times 10^{2}$ |
| Total *Rhizobia* (cfu) | $1.9 \times 10^{3}$ | $9.4 \times 10^{3}$ | $5.0 \times 10^{3}$ |
| Total *Bacillus* (cfu) | $5.0 \times 10^{5}$ | $11.0 \times 10^{6}$ | $3.0 \times 10^{5}$ |
| Total phosphate dissolving bacteria (cfu) | $1.7 \times 10^{4}$ | $6.9 \times 10^{4}$ | $2.6 \times 10^{4}$ |

## RESULTS AND DISCUSSION

### *Maize growth and development at 85 days from maize sowing*

### *The preceded winter crops*

Ear leaf area and plant dry weight at 85 days from maize sowing was affected significantly by the preceded winter crops in the combined data across 2012/2013 and 2013/2014 seasons (Figure 1). All the studied maize traits were increased after berseem cutting compared to those grown after sugar beet or wheat. Berseem residues increased ear leaf area by 5.19 and 7.74 % compared to those followed sugar beet and wheat, respectively (Figure 1). Also, berseem residues increased *($P \leq 0.05$)* plant dry weight by 1.64 and 3.29 % compared to those followed sugar beet and wheat, respectively (Figure 1). These data reveal that the preceded winter crops had different allelopathic effects on chemical and biological soil properties which reflected on ear leaf area and plant dry weight at 85 days from maize sowing (Table 1).

### *Chemical soil properties*

The forage legume (berseem) residues increased some soil nutrients in comparison with those by sugar beet or wheat which confirming the increase in availability of the soil nutrients in the rhizosphere of intercropped maize roots at 85 days from maize sowing (Table 1). Berseem residues increased soil N, P and K contents of the subsequent maize plants compared to those by sugar beet or wheat (Table 1). These results indicate that berseem enhanced N, P and K availability to the subsequent maize plants which reflected positively on maize growth and development. The increase in soil N availability to subsequent maize plants was attributed to high ability of N fixation process of the legume crop (Table 1) where there was high content of biological N in the roots and residues of lucerne and red clover (Maiksteniene and Arlauskiene, 2004). Such effect was expected because of 40 to 75 percent of the total N contained in a legume cover crop is available in the soil for subsequent crops, depending on environmental conditions (Baldwin, 2006). These results are in harmony with those obtained by Abdel-Galil *et al.* (2015) who revealed that fahl berseem added more N to the subsequent cereal crop.

Also, the increase in soil P availability to the subsequent maize plants was due to lower soil Ca content after cutting berseem than those by sugar beet or wheat (Table 1). The mobility in soil is dependent on the chemical form of the element used. P can react with excess Ca to form unavailable compounds in the soil (Beegle and Durst, 2002). The increase in P availability from phosphate rock (PR) dissolution and is possibly further enhanced by the legume due to higher Ca uptake and acidification of the rhizosphere (Randhawa, 2003). A residual benefit of the legumes on the growth of the subsequent cereal crop due to enhanced P uptake (Nuruzzaman *et al.*, 2004).

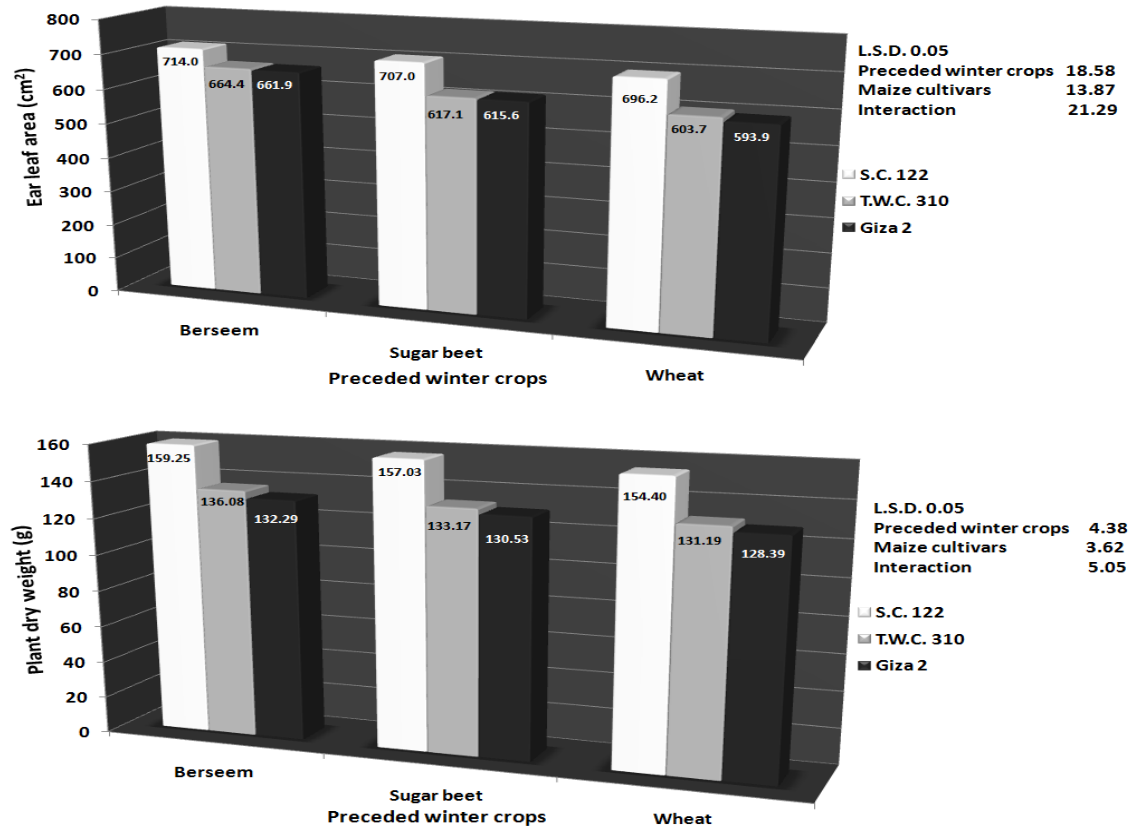


**Figure 1.** Ear leaf area and plant dry weight at 85 days from maize sowing as affected by preceded winter crops, maize cultivars and their interaction, combined data across 2012/2013 and 2013/2014 seasons.

These results show that berseem increased soil P availability that could be stimulated early root formation and growth of maize compared to those followed sugar beet or wheat. These results are in parallel with those obtained by McLenaghen *et al.* (2004) who found that lupin as a green manure winter crop in combination with PR can enhance P nutrition of the subsequent maize crop due to the capacity of lupin to solubilize the sparingly soluble (reactive) PR.

Also, Nuruzzaman *et al.* (2004) demonstrated that a residual benefit of the legumes on growth of the subsequent cereal crop due to enhanced P uptake. The concurrent increase in growth and P concentrations indicated that the legumes somehow enhanced the availability of P for uptake by the cereal crop. They concluded that the beneficial effect of these legumes was due to effects on soil P status other than mineralization of root residues. Also, Nuruzzaman *et al.* (2005) found that some legumes increase growth and P uptake of the following cereal and the positive pre-crop effect of legumes on cereals is due to P mobilization or P release from legume residues. Moreover, Hassan *et al*. (2010) indicated that the legumes could differentially affect the dynamics of organic and inorganic P pools and the capacity of the following wheat to utilize these pools.

Moreover, the increase in soil K availability to the subsequent maize plants was due to berseem is clover's deep-growing roots that could be accelerated the weathering of the experimental soil released K into the soil (Table 1), especially Peaslee and Moss (1966) reported that reduced photosynthesis in K deficient leaves was ascribed to reduced stomatal apertures and could be reversed by supplying K. K accumulation during the early growth stages of maize is faster than that of dry matter. The dilution effects and translocation of K from the leaves and stalks to the cob and grains cause a rapid decline in K in the vegetative shoot (Welch and Flannery, 1985). Perennial legumes such as lucerne, with their deep root systems, import additional K (Teit 1990) to the soil that is accessible to succeeding crops (Witter and Johansson 2001).

These results are in accordance with those obtained by Patriquin (1998) who showed that clovers accelerate the weathering of rock, which releases mineral nutrients such as K into the soil, and increases the depth of topsoil. Also, Maiksteniene and Arlauskiene (2004) reported that after all the legume crops the content of available P and K increased when fertilizing with green manure or farmyard manure. These results indicate that the preceded berseem crop residues had the ability of enriching the N content of the experimental soil by fixing N from the air, in addition to improve in the productivity of soil (soil P and K availability) for the subsequent maize. With regard to growth inhibiting, maize growth and development was affected negatively by residues of sugar beet or wheat as a preceded winter crop, there was high concentration of ferulic acid in the experimental soil after sugar beet or wheat harvest (Table 1). Previous researchers have mentioned that sugar beet or wheat residues has phenolic compounds that appear to have toxic effects on maize seedlings, these effects were most probably due to phenolic compounds like ferulic acid. Ferulic acid reduced percent germination of maize grains and inhibited maize root growth (Abdaoui, 1991). Also, the activities of hydrolytic enzymes in maize plant could be affected negatively by some phenolic compounds which reflected a mechanism of action for the natural maize growth inhibitors (Devi and Prasad, 1992). Phenolics are the most common water-soluble allelochemicals known to play a significant role in plant— plant interactions, including allelopathy (Batish *et al*., 2002). Consequently, organic substances can interfere with basic processes of receiver plants as photosynthesis, cell division, respiration and protein synthesis (Duke and Dyan, 2006). Also, ferulic acid may ultimately reduce plant photosynthesis and cause reduction of maize dry weight through wheat residues that impede water absorption by the maize root and radicle (Saffari *et al*., 2010).

Also, sugar beet or wheat as a preceded crop increased soil Cl, meanwhile, it caused a reduction in soil Fe, Mg and Mn contents than those by berseem (Table 1). With respect to soil Cl availability, sugar beet or wheat residues increased soil Cl to the subsequent maize plants that had a negative interference on maize growth and development compared to those followed berseem. It is known that accumulation of Cl in the root tissue is disruptive to membrane uptake mechanisms, and these results in increased translocation of Cl to the shoots (Yousif *et al*., 1972). Moreover, Fe plays a key role in maize growth and development because of its physico-chemical properties. Fe is an irreplaceable cofactor in many redox or electron transport reactions occurring within cells. Fe in aerated aqueous solution is highly insoluble in its oxidized, ferric, form ($Fe^{+3}$), and this insolubility is maximum at pH 7. This property considerably restricts Fe availability for plants growing on neutral soils, and is responsible for Fe chlorosis, a prevalent nutritional plant disorder (Miller *et al*., 1984). Furthermore, the increase in soil Fe availability to the subsequent maize plants may be due to its role in the composition of chlorophyll synthesis (Cui *et al*., 2010).

Furthermore, deficiency of Mg and Mn in the soil could lead to negative effects on the efficiency of photosynthetic process of the maize plant where Mg is central atom in chlorophyll; meanwhile, Mn is an activator in several important enzymes including the chloroplast RNA polymerase (Marschner, 1995). Finally, Mg is involved in numerous physiological processes during plant growth and development (Marschner, 2012). Accordingly, sugar beet and wheat residues decreased ear leaf area and plant dry weight at 85 days from maize sowing than those by berseem as preceded winter crop. Therefore, these results reveal that sugar beet or wheat residues with adequate soil moisture could be partially decomposed, leaving more residues affecting soil N, P, K, Mg, Mn and Fe immobilization, as well as, increasing ferulic acid content which reducing the soil nutrient availability during the maize season.

***Biological soil properties***

Organic N is not available to maize plant until it has been converted to an inorganic form by soil bacteria. There was a significant increase in ear leaf area and plant dry weight at 85 days from maize sowing after berseem cutting when compared to those followed sugar beet or wheat (Figure 1). The forage legume (berseem) residues promoted N-fixing bacteria (*Azotobacter* and *Rhizobia* sp.), *Bacillus* and phosphate dissolving bacteria (plant growth promoting bacteria 'PGPR') compared to those by sugar beet or wheat (Table 2). Obviously, berseem promoted growth of PGPR (Table 2) and became more active for increasing soil N, P and K availability for the subsequent maize plants after berseem cutting than those by sugar beet or wheat. Reduction in PGPR populations could be considered as a biological pool affect soil N, P and K dynamic, especially *Bacillus* species led to yield increases in maize (Pal, 1999). *Bacillus* species used as biofertilizers may have direct effects on plant growth through the synthesis of plant growth hormones (Amer and Utkheda, 2000).

Also, phosphate solubilizing *Bacillus* spp. stimulates plant growth through P nutrition (Whitelaw e*t al.*, 1997), increasing the uptake of N, P, K and Fe and hence PGPR can enhance the growth and development of associated crops by improving nutrient uptake (Biswas *et al*., 2000). Some of the above bacteria may also solubilize inorganic phosphate, making soil P otherwise remaining fixed available to the plants due to excretion of organic acids (Whitelaw, 2000). Also, large proportion of P in the experimental soil (Table 1) could be insoluble and therefore unavailable to the subsequent maize plants and hence phosphate solubilization is a desired property to be present in the bacteria. These data reveal that the ability of the forage legume crop depended on PGPR which played an important role in soil nitrifiers and immobilization of N in organic forms.

Organic P availability depends on microbial activity to breakdown the organic matter and releases this element into available forms. Thus, availability of organic P for the subsequent maize plants is very dependent on the preceded winter field crops; there was better soil environment for the biological activity and nutrient cycling (Arya *et al*., 2007) after berseem cutting compared to those by sugar beet or wheat. The data clearly indicate that there was a significant increment in ear leaf area and plant dry weight after berseem cutting compared to those followed sugar beet or wheat. Accordingly, berseem formed better under-ground conditions for maize growth and development. Obviously, phosphate dissolving bacteria were able to solubilize phosphates and act as plant growth promoting bacteria; *Bacillus* sp. affected significantly dry weight of maize plants as was found by Jarak *et al.* (2012).

These findings imply that berseem residues increased the efficiency of photosynthetic process through promoting soil bacteria activity that reflected positively on ear leaf area and plant dry weight at 85 days from maize sowing compared to those followed sugar beet or wheat. These results are in agreement with the findings of Gilbert (2000) who reported that only legumes producing above 2 Mg per ha of biomass (50 kg N per ha) would be expected to provide better yield response for maize in the following season. Also, Abbasi *et al.* (2009) found that maize traits were increased after white clover alone or combination with P.

On the other hand, sugar beet or wheat residues had an adverse effect on ear leaf area and plant dry weight at 85 days from maize sowing than those followed berseem. These results reveal that sugar beet or wheat residues did not accelerate growth of PGPR than those by berseem (Table 2). It is known that phenolics consist of more than one aromatic ring, bearing one or more hydroxyl functional groups. They originate from plant materials and industrial products/wastes, which enter the soil either as leachates or as particulate matter (Hättenschwiler and Vitousek, 2000). Once integrated into the soil, phenolics can control below-ground processes, including soil organic matter decomposition (Freeman *et al*., 2001) and nutrient cycling (Kraus *et al*., 2004). These results reveal that sugar beet or wheat residues as preceded crop decreased soil biological activity that affected negatively soil nutrient availability which restricted growth and development of ear leaf area at 85 days from maize sowing than those followed berseem. Therefore, ear leaf area had adverse effects on the translocated photosynthates from the leaf to the different parts of the plant during growth and development at 85 days from maize sowing than those followed berseem.

***Maize cultivars***

Ear leaf area and plant dry weight at 85 days from maize sowing were differed significantly among maize cultivars in the combined data across 2012/2013 and 2013/2014 seasons (Figure 1). Maize cultivar S.C. 122 had the highest values *(P ≤ 0.05)* of ear leaf area and plant dry weight compared to the other cultivars. These results are mainly due to genetic potential among the studied maize cultivars. Naturally, genetic information directs the synthesis and development of enzymes which are critical in all metabolic process within the plant. Normal growth of a maize cultivar depends on the coordinated regulation of sink and source metabolism. So, it may be possible that genetic potential of maize cultivar S.C. 122 may produce suitable canopy architecture with leaf angle which could be induced a deeper root system and a faster horizontal root development compared to the other maize cultivars, this balance ensures efficient use of all nutrients by all parts of maize cultivar S.C. 122. This variability could be a key to crop improvement. There were significant genetic differences for morphological parameter among maize genotypes (Ihsan *et al*., 2005).

The superiority of maize hybrids over the open pollinated cultivars was indicated by various investigators (El-Sheikh, 1999 and Radwan *et al*., 2001). In maize crop canopy, leaf area and vertical leaf area profile influence the interception and utilization of solar radiation which consequently drive dry matter accumulation and results the grain yield (Valentinuz and Tollenaar, 2006). It is evident that maize cultivar S.C. 122 had high capacity of leaves to assimilate carbon and export sucrose that reflected positively on ear leaf area and plant dry weight. Differences in growth of maize cultivars were mainly due to their leaf area expansion rate (Akmal *et al*., 2010). Consequently, maize cultivar S.C. 122 had high capacity of root system that can make a larger volume of soil available for root extraction of water and nutrients compared to the others. These results are in agreement with those reported by Hokmalipour and Darbandi (2011) who showed that leaf area index and leaf dry weight differed significantly among three maize hybrids.

***The interaction between the preceded winter crops and maize cultivars***

Ear leaf area and plant dry weight were affected significantly by the interaction between the preceded winter crops and maize cultivars in the combined data across 2012/2013 and 2013/2014 seasons (Figure 1). Maize cultivar S.C. 122 that followed berseem had the highest ear leaf area and plant dry weight, meanwhile, maize cultivar Giza 2 that followed wheat had the lowest ear leaf area and plant dry weight compared to the other treatments. These data indicate that berseem residues increased ear leaf area and plant dry weight of maize cultivar S.C. 122 at 85 days from maize sowing compared to those followed sugar beet or wheat. Increased ear leaf area and plant dry weight of S.C. 122 cultivar after berseem cutting was supported by the findings of Cox *et al*. (1993) and Sumi and Ketayama (2000) who reported that N promoted higher leaf area development and reduced rate of senescence.

Additionally, plant growth promoting bacteria (PGPR) after berseem cutting may be resulted in proliferated root architecture of maize cultivar S.C.122 where nitrate transporter genes of this cultivar could be induced by available soil N content after berseem cutting compared to the other treatments. Roots of S.C. 122 cultivar could be well ramified within the soil volume which led to increase capacity of the plant to absorb more water and nutrients after berseem cutting compared to the other treatments. Changes in root architecture similar to those induced by PGPR are due to the changes in nitrate availability in the medium (Wiersum 1958).

Consequently, it may be possible that root of maize cultivar S.C.122 elongated with the increase in efficiency of photosynthesis process through soil nutrient availability. Maize cultivar S.C. 10 was superior in N uptake than T.W.C. 310 and Giza 2 (Shafshak *et al*., 1994). Additionally, combined inoculations with $N_2$-fixing and P solubilizing bacteria were more effective than single microorganisms providing a more balanced nutrition for plants (Belimov *et al*., 1995), and maize cultivars are known to vary in P uptake and utilization efficiencies, as well as in adaptability to different soil types (Machado *et al*., 1999). Moreover, it has been found that rhizobial inoculation to maize cultivar Malaviya 1 resulted in proliferated root architecture (Mantellin and Tourain, 2004).

Accordingly, it is worthy to note that growing wheat or sugar beet as preceded crops caused significant reduction in ear leaf area and plant dry weight of maize cultivar Giza 2 or T.W.C. 310 in 85 days from maize sowing as a result of high concentrations of ferulic acid in the experimental soil (Table 1). Optimal amount of P and K in the soil cannot be utilized efficiently if N is deficient in plants where N mediates the utilization of P, K and other elements in plants (Brady, 1984). Hence, N is a component of protein and nucleic acids and when N is suboptimal, growth is reduced (Haque *et al*., 2001). These data reveal that there was effect *(P ≤ 0.05)* of the preceded winter crop x maize cultivars on ear leaf area and plant dry weight.

***Maize yield and its attributes***

***The preceded winter crops***

Plant and first ear heights, ear length and diameter, ear weight, shelling, grain yields per plant and per ha, as well as, soybean seed yield/ha were affected significantly by the preceded winter crops in the combined data across 2012/2013 and 2013/2014 seasons, meanwhile, number of ears/plant and number of rows/ear were not affected (Table 3). Berseem residues caused a significant increase in plant and first ear heights, ear length and diameter, ear weight, shelling, grain yields per plant and per ha, as well as, soybean seed yield/ha compared to those followed sugar beet or wheat.

Berseem residues increased significantly grain yield/ha by 4.84 or 11.70 % compared to those followed sugar beet or wheat, respectively (Table 3). Berseem residues increased *(P≤0.05)* average of plant and first ear heights by 2.84 and 3.57 %, respectively, compared to those followed sugar beet, meanwhile this average reached 4.26 and 7.59 %, respectively, when compared to those followed wheat. These data may be due to the increase in length and number of internodes as a result of rapid cell division and elongation.

**Table 3.** Effect of preceded winter crops, maize cultivars and heir interaction on maize yield and its attributes, combined data across 2012/2013 and 2013/2014 seasons

| Preceded winter crops | Plant height (cm) | | | | Ear height (cm) | | | | Number of ears/plant | | | | Ear length (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S.C.122 | T.W.C.310 | Giza 2 | Mean | S.C.122 | T.W.C.310 | Giza 2 | Mean | S.C.122 | T.W.C.310 | Giza 2 | Mean | S.C.122 | T.W.C.310 | Giza 2 | Mean |
| **Berseem** | 290.9 | 282.6 | 284.7 | **286.0** | 187.3 | 180.9 | 180.1 | **182.7** | 1.43 | 1.20 | 1.02 | **1.21** | 23.35 | 21.60 | 20.70 | **21.88** |
| **Sugar beet** | 284.5 | 276.4 | 273.4 | **278.1** | 182.0 | 173.9 | 173.3 | **176.4** | 1.40 | 1.16 | 1.01 | **1.19** | 22.60 | 20.90 | 19.45 | **20.98** |
| **Wheat** | 279.8 | 273.1 | 270.1 | **274.3** | 178.8 | 166.5 | 164.2 | **169.8** | 1.38 | 1.15 | 1.00 | **1.17** | 20.50 | 18.85 | 17.70 | **19.01** |
| **Average of maize cultivar** | **285.1** | **277.3** | **276.0** | **279.4** | **182.7** | **173.7** | **172.5** | **176.3** | **1.40** | **1.17** | **1.01** | **1.19** | **22.15** | **20.45** | **19.28** | **20.62** |
| **L.S.D. 0.05 Preceded winter crops** | | | | **4.22** | | | | **5.17** | | | | **N.S.** | | | | **2.11** |
| **L.S.D. 0.05 Maize cultivars** | | | | **3.76** | | | | **4.62** | | | | **0.22** | | | | **1.62** |
| **L.S.D. 0.05 Interaction** | | | | **4.75** | | | | **5.39** | | | | **N.S.** | | | | **2.29** |
| **Sole maize** | 298.5 | 292.3 | 293.7 | **294.8** | 194.1 | 189.2 | 189.6 | **190.9** | 1.25 | 1.06 | 0.95 | **1.08** | 19.66 | 17.72 | 16.86 | **18.08** |

**Table 3. Continued**

| Preceded winter crops | Ear diameter (cm) | | | | Number of rows/ear | | | | Ear weight (g) | | | | Grains weight/ear (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S.C.122 | T.W.C.310 | Giza 2 | Mean | S.C.122 | T.W.C.310 | Giza 2 | Mean | S.C.122 | T.W.C.310 | Giza 2 | Mean | S.C.122 | T.W.C.310 | Giza 2 | Mean |
| **Berseem** | 4.87 | 4.63 | 4.49 | **4.66** | 13.18 | 12.85 | 12.74 | **12.92** | 224.99 | 207.24 | 187.66 | **206.63** | 191.98 | 166.72 | 140.83 | **166.51** |
| **Sugar beet** | 4.82 | 4.50 | 4.37 | **4.56** | 13.18 | 12.86 | 12.77 | **12.93** | 214.98 | 198.05 | 178.04 | **197.02** | 184.30 | 158.00 | 132.33 | **158.21** |
| **Wheat** | 4.69 | 4.38 | 4.22 | **4.43** | 13.21 | 12.83 | 12.74 | **12.92** | 206.93 | 185.39 | 164.91 | **185.74** | 175.53 | 146.23 | 120.63 | **147.46** |
| **Average of maize cultivar** | **4.79** | **4.50** | **4.36** | **4.55** | **13.19** | **12.84** | **12.75** | **12.92** | **215.63** | **196.89** | **176.87** | **196.46** | **183.93** | **156.98** | **131.26** | **157.39** |
| **L.S.D. 0.05 Preceded winter crops** | | | | **0.19** | | | | **N.S.** | | | | **18.81** | | | | **17.15** |
| **L.S.D. 0.05 Maize cultivars** | | | | **0.16** | | | | **N.S.** | | | | **13.66** | | | | **12.27** |
| **L.S.D. 0.05 Interaction** | | | | **0.21** | | | | **N.S.** | | | | **23.34** | | | | **19.42** |
| **Sole maize** | 4.43 | 4.14 | 4.09 | **4.22** | 13.03 | 12.78 | 12.71 | **12.84** | 181.99 | 163.96 | 151.65 | **165.86** | 148.06 | 123.51 | 105.83 | **125.80** |

**Table 3. Continued**

| Preceded winter crops | Shelling (%) | | | | Grain yield/plant (g) | | | | Maize grain yield/ha (ton) | | | | Soybean seed yield/ha (ton) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S.C.122 | T.W.C.310 | Giza 2 | Mean | S.C.122 | T.W.C.310 | Giza 2 | Mean | S.C.122 | T.W.C.310 | Giza 2 | Mean | S.C.122 | T.W.C.310 | Giza 2 | Mean |
| **Berseem** | 85.94 | 80.45 | 75.05 | **80.48** | 262.08 | 197.73 | 136.13 | **198.64** | 7.11 | 5.60 | 4.19 | **5.63** | 1.74 | 1.78 | 1.83 | 1.78 |
| **Sugar beet** | 85.73 | 79.78 | 74.33 | **79.94** | 250.93 | 179.63 | 129.32 | **186.62** | 6.84 | 5.25 | 4.04 | **5.37** | 1.66 | 1.69 | 1.75 | 1.70 |
| **Wheat** | 84.83 | 78.88 | 73.15 | **78.95** | 235.17 | 163.39 | 117.39 | **171.98** | 6.52 | 4.86 | 3.76 | **5.04** | 1.59 | 1.63 | 1.67 | 1.63 |
| **Average of maize cultivar** | **85.50** | **79.70** | **74.17** | **79.79** | **249.39** | **180.25** | **127.61** | **185.75** | **6.82** | **5.23** | **3.99** | **5.34** | 1.66 | 1.70 | 1.75 | 1.70 |
| **L.S.D. 0.05 Preceded winter crops** | | | | **1.44** | | | | **24.73** | | | | **0.53** | | | | **0.13** |
| **L.S.D. 0.05 Maize cultivars** | | | | **1.17** | | | | **18.15** | | | | **0.35** | | | | **0.08** |
| **L.S.D. 0.05 Interaction** | | | | **1.68** | | | | **26.44** | | | | **0.66** | | | | **0.15** |
| **Sole maize** | 81.36 | 75.33 | 69.79 | **75.49** | 172.97 | 120.11 | 98.63 | **130.57** | 8.08 | 5.62 | 4.57 | **6.09** | | | | **2.83** |

These results are in accordance with those obtained by Idikut *et al.* (2009) who showed that there were significant effects of previous crops (chickpea and wheat) on the first ear height and ear length. Also, berseem residues increased ear length and diameter, ear weight and shelling compared to those followed sugar beet or wheat. Berseem residues increased *(P≤0.05)* average of ear length and diameter by 4.28 and 2.19 %, respectively, compared to those followed by sugar beet, meanwhile this average reached 15.09 and 5.19 %, respectively, when compared to those followed wheat. So, it may be possible that berseem residues increased strength of physiological sink of maize plants (ear length and diameter) by improving edaphic conditions during growth and development of maize.

It is known that N is an important factor for boosting up the yield of cereals and is very important for vegetative growth, as well as, higher yield (Shrivastava and Sinha, 1992). Moreover, Sahoo and Panda (2001) reported that length of ears increased with increasing level of P. The increase in ear length of maize with P application close to sowing probably may be due to increased in number of leaves per plant and mean leaf area (Amanullah *et al*., 2009). These results may be due to berseem residues decreased intra-specific competition between maize plants for climatic and edaphic environmental resource which led to high rate of photosynthesis in the plant that expressed an increase in ear characteristics.

Moreover, berseem residues increased grain yield per plant by 6.44 and 15.50 % compared to those followed sugar beet and wheat, respectively. These results could be due to soil N, P and K were more available to subsequent maize plant after berseem cutting (Table 1). Consequently, there is an increase in dry matter accumulation (Figure 1) that reflected on ear weight and shelling (Table 3). Cobs may be considered as temporary sink and the stored photosynthates were translocated to grains during their development. The population of plants per square meter (density) and arrangement of individual plants within a square meter determine nutrient use and grain yield of maize (Wade *et al*., 1988). Certainly, grain yield per unit area increases with plant density until the increase in yield attributable to plants is offset by decline in mean yield per plant (Tollenaar and Wu, 1999).

Also, grain yield per plant had positive and highly significant correlation with fresh ear weight, cob length, ear diameter and shelling percentage (Eleweanya *et al.*, 2005). It seems to be there was better soil environment for the biological activity (Table 2) and nutrient cycling (Arya *et al*., 2007) as a result of a mix of living rhizobia and dead berseem roots near the experimental soil surface. These results reveal that berseem as preceded crop increased soil nutrient availability than those by sugar beet or wheat for maize plants in the following season, especially P is another essential nutrient required to increase maize yield (Onasanya *et al*., 2009). Clearly, growing maize after sugar beet or wheat harvest could be delayed phenology, and significantly reduced shelling percentage and grain yield, indicating that maize crop was subjected to P-deficiency during the early growth stage (Amanullah and Zakirullah, 2010).

These results are in accordance with those found by Hussanin and Haq (2000) who indicated that the lower grain yield and shelling percentage in the absence of P indicating higher demand for P fertilizer. Also, Bloem and Barnard (2001) found that maize yields after rotation with legumes were generally higher than the control treatments. They added that after the effect of N was accounted for via the N – corrected yield, it was evident that additional yield increases of 10% (average). Moreover, Fischer *et al.* (2002) reported that maize after vetch with zero tillage yielded well. On the other hand, Fore (2005) indicated that when maize directly follows sugar beets, it is frequently not as productive as corn after soybeans or other rotational crops. He added that maize following sugar beets is stunting, shortened internodes, purpling and reduction in vigor. In another study, Ibrikci *et al.* (2005) suggested that P deficiency was invariably a common crop growth and yield limiting factor. Under K deficient soils, photosynthesis is significantly reduced (Hermans *et al*., 2006) which is responsible for low yield in maize (Amanullah *et al*., 2007).

On the other hand, legumes, in contrast to cereals, have a beneficial effect on grain yield of subsequent cereal crops (Olesen *et al.,* 2007). Finally, Marandu *et al.* (2013) showed that the higher maize grain yields in plots where the legumes were grown in rotation than that under continuous maize cropping could be attributed to the contribution of N by the legumes when they were rotated with maize. Also, they revealed that the maize yields following rotation with each of the three legumes were significantly higher than those under continuous maize. Moreover, Ali *et al.* (2015) showed that legumes as preceding crop had increased significantly grain yield (5104 ka/ha) compared to fallow as preceding practice (3185 kg/ha).

***Maize cultivars***

Maize cultivars differed significantly for plant and ear heights, number of ears/plant, ear length and diameter, ear weight, shelling, grain yields per plant and per ha, as well as, soybean seed yield/ha in the combined data across 2012/2013 and 2013/2014 seasons, meanwhile, number of rows/ear was not affected (Table 3). Maize cultivar S.C. 122 had the highest values of plant and ear heights, number of ears/plant, ear length and diameter, ear weight, shelling, grain yield/plant, grain yield/ha but it caused a significant reduction in soybean seed yield/ha compared to the other maize cultivars. Maize cultivar S.C. 122 was the tallest (285.1 and 182.7 cm) in plant and ear heights, respectively, compared to the others. These results could be attributed to an increase in length and number of internodes. This finding was in agreement with the results of Beirag *et al.* (2011) who reported that there were genetic differences among maize hybrids in plant and ear heights.

Also, the results in Table (3) show that S.C. 122 cultivar gave longer ears (22.15 cm) compared to the other maize cultivars. These results are in good agreement with those obtained by Soliman *et al*. (1995) who mentioned that there was differential variation of ear length for different maize cultivars. Moreover, the data indicate that ears diameter of S.C. 122 cultivar exceeded those of T.W.C. 310 and Giza 2, respectively. The difference in the genetical constituent of different maize cultivars might account much to difference in length and size of ears (Abo-Shetaia *et al*., 2002). Superiority of SC 122 cultivar may be due to increase fertilized embryos which led to grow kernels with an increase in ear length and diameter, especially the grain : ear weights ratio was higher in S.C. 122 cultivar than T.W.C. 310 or Giza 2 cultivar. There was a positive and highly correlated relationship among ear fill, ear length and ear circumference with grain weight/ear (Paudel, 2009). Furthermore, the highest ear weight was recorded by S.C. 122 cultivar compared to the others. It is apparent that S.C. 122 cultivar that was prolific compromised ear weight probably due to the interplay of genotype and intra-plant competition. Clearly, the significant differences among the maize cultivars for ear characteristics traits confirmed their genetic diversity.

Maize cultivar S.C. 122 yielded 30.40 and 70.92 % over than the two maize cultivars; T.W.C. 310 and Giza 2, respectively. These results may be due to canopy of maize cultivar S.C. 122 intercepted more solar radiation that led to increase in efficiency of photosynthesis process and more photosynthates as a result of extended leaf area (Figure 1) which were partitioned to the developing ears compared to the other cultivars. Clearly, these results reveal that S.C. 122 was more effective in translocating photosynthates from leaves and stalks to the developing ears than T.W.C. 310 or Giza 2. High yield maize hybrids are more effective in translocating photosynthates from leaves and stalks to grain but have more mechanical stress on the stalk due to the greater weight of ears and lower concentrations of soluble solids in the stalks (Campbell, 1964).

Accordingly, the differences among the maize cultivars might be due to genetic differences that reflected on dominate phenotype of maize cultivar S.C. 122 which resulted in more dry matter accumulation than maize cultivar T.W.C. 310 or Giza 2. Maize yield is strongly depends on leaves efficiency for absorption of solar radiation for photosynthesis process (Mouhamed and Ouda, 2006). In this concern, Storck *et al*. (2007) reported that there is variability among hybrids which does not follow a tendency of genetic variability between single, three-way and double hybrids. Similar results were observed by Abdel-Galil *et al.* (2014) who reported that maize cultivar S.C.166 had the highest grain yields per plant and per ha, meanwhile, maize cultivar S.C. 122 had the lowest grain yields per plant and per ha.

### *Interaction between the preceded winter crops and maize cultivars*

Plant and first ear heights, ear length and diameter, ear weight, shelling, grain yields per plant and per ha, as well as, soybean seed yield/ha were affected significantly by interaction between the preceded winter crops and maize cultivars in the combined data across 2012/2013 and 2013/2014 seasons, meanwhile number of ears/plant was not affected (Table 3). The highest values of plant and first ear heights, ear length and diameter, ear weight, shelling, grain yields per plant and per ha were obtained by growing maize cultivar S.C. 122 after berseem as a preceded crop.

These data show that the expression of plant and ear heights depends on the cultivar and the environment. It seems to be maize cultivar S.C. 122 interacted with positive allelopathic effects after berseem cutting and augmented plant and first ear heights. It is known that maize genotypes differ in the rate of N absorption and utilization (Kamprath *et al*., 1982). Moreover, the soil fertility status is improved by activating the soil microbial biomass (Belay *et al*., 2001). Accordingly, plant height has been described as a measure of growth related to the efficiency in exploitation of environmental resources (Alimohammadi *et al*., 2011).

Also, the higher ear leaf area of S.C. 122 cultivar resulted in higher grains and its weight and hence yielded higher grain yield. Leaf photosynthesis can be influenced by many plant factors such as environmental factors such as light, temperature, nutrition, and water availability (Lieth and Pasian, 1990). Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Sharma and Mittra, 1991). Soil pH, soil texture, the amount of P applied, the presence of other elements - like Fe, Mn and Ca in the soil, microbial activity and the time of P application affected the availability of P (Yash *et al*., 1992). It is known that grain yield is a function of genotype x environment interaction (Abo-Shetaia *et al*., 2002 and Annicchiarico, 2002). These observations supporting better root development of S.C. 122 cultivar after berseem cutting, which led to higher yield attributes. Therefore, difference in grains weight was results of assimilates and it's partitioning to the grains. There was interaction effect between maize cultivars and P on ear weight of maize and grain yield (Hussain *et al*., 2007). Also, Akmal *et al*. (2010) indicated that 1000 grains weight (g) differed significantly for maize cultivars and N levels. N being an essential constituent of plant tissue is involved in cell division and cell elongation (Gul *et al*., 2015).

On the other hand, it seems to be that soybean plants were suffered from S.C. 122 cultivar when grown together especially after berseem as a preceded crop. Maize cultivar S.C. 122 could be decreased solar radiation around the adjacent soybean plants as a result of extended ear leaf area of this cultivar (Figure 1) which reflected negatively on soybean productivity (Table 3). On the other hand, growing maize cultivar Giza 2 after wheat recorded the lowest values of grain yield and its attributes but it had a positive effect on soybean productivity under intercropping culture especially after berseem cutting.

These data indicate that each of these two factors act dependently on all the studied traits of maize plant meaning that maize cultivars responded differently ($P \leq 0.05$) to the preceded winter crops for plant and first ear heights, ear length and diameter, ear weight, shelling, grain yields per plant and per ha, as well as, soybean seed yield/ha.

## CONCLUSION

It could be concluded that the preceded berseem crop has positive chemical and biological effects on soil fertility that improved growth and development of all the tested cultivars under intercropping culture. This investigation showed that maximum yield was obtained by S.C. 122 cultivar after berseem cutting. Although S.C. 122 cultivar had more yield potential than T.W.C. or Giza 2 cultivar, however it is not suitable for intercropping culture.

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