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Increasing Chickpea Quality and Agroecosystm Sustainability Using Organic and Natural Resources

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Abstract**—**In order to increase in chickpea quality and agroecosystem sustainability, field experiments were carried out in 2007 and 2008 growing seasons. In this research the effects of different organic, chemical and biological fertilizers were investigated on grain yield and quality of chickpea. Experimental units were arranged in split-split plots based on randomized complete blocks with three replications. The highest amounts of yield and yield components were obtained in G1×N5 interaction. Significant increasing of N, P, K, Fe and Mg content in leaves and grains emphasized on superiority of mentioned treatment because each one of these nutrients has an approved role in chlorophyll synthesis and photosynthesis ability of the crop. The combined application of compost, farmyard manure and chemical phosphorus (N5) had the best grain quality due to high protein, starch and total sugar contents, low crude fiber and reduced cooking time.

Keywords**—**Agroecosystem, sustainability, chickpea, natural resources.

I. INTRODUCTION

THE chickpea (*Cicer arietinum* L.) as a healthy vegetarian food has an important role in human food and domestic animal feed in Iran. It is a cheap source of high quality protein in the diets of millions of people in developing countries, who cannot afford animal protein for balanced nutrition. In addition to proteins, it is a good source of carbohydrates, minerals and trace elements [19]. Also chickpea play a key role in organic cropping systems. In such agro ecosystem with limited availability of nitrogen, chickpea potentially constitute both a cash crop and a source of N incorporation into the system via biological nitrogen fixation. The growing chickpea in crop rotation increased crop productivity and sustainability for the semi-arid region. Maintenance and management of soil fertility is the core of development of sustainable food production systems. To be sustainable, organic farming needs to be self-sufficient in nitrogen (N) through the fixation of atmospheric di-nitrogen (N2) by legumes [5], recycling of crop residues (green manures) [14] and the application of natural resources such as farmyard manure, compost and biofertilizer [33].

Green manures application to the soil is considered a good management practice in all agricultural production system because of increasing cropping system via sustainability by reducing soil erosion, improving soil physical properties and increasing soil organic matter and fertility levels [9, 31]. A major benefit attributed to the green manure and organic fertilizer is the increased organic matter of the soil. Weed suppression derived from the allelopathic effect of green manure has become an important method to weed control in sustainable agriculture. Nitrogen accumulations by leguminous green manure range from 40 to 200 lbs.acre^{-1} [27].

Forage legumes are valuable members in crop rotations because they generate income from grazing or haying and still contribute nitrogen from regrowth and root residues. Furthermore they help to recycle other nutrients on the farm. Phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), and other nutrients are accumulated by green manure during a growing season and increased fertility of agroecosystms. During decomposition of organic matter, carbonic and other organic acids are formed as a byproduct of microbial activity. These organic acids react with insoluble mineral rocks and phosphate precipitates, releasing phosphates and exchangeable nutrients [27].

Phosphorus is present as mineral deposits, which are a nonrenewable natural resource. There is global concern about the energy and costs involved in mining the phosphate rock and its transport to manufacturing sites, as well as in the manufacture of different fertilizers and their transport to farm fields and application to the crops. Photosynthesis and stomatal conductance are reduced by P deficiency [17] and, conversely, increases P increased photosynthesis [16]. Phosphate solubilizing bacteria are also known to increase phosphorus uptake resulting in better growth and higher yield of crop plants [2, 36]. The combined inoculation of Rhizobium and phosphate solubilizing bacteria has increased nodulation, growth and yield parameters in chickpea [2, 23, 36].

Trichoderma sp. have long been known as effective antagonists against soil borne plant pathogenic fungi [4, 21] and promote vegetative growth in plant. The study of combining these organisms and organic manures is of great potential value to organic agriculture in order to avoid chemical fertilizers and pesticides. The present research is going to introduce a sustainable soil fertility system, evaluates

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the combined effect of biofertilizers and organic manure such green manure, compost and farmyard manure on chickpea.

II. MATERIAL AND METHODS

The field experiments were conducted at Agricultural Research Center of Sanandaj in Kurdistan province of Iran during the 2007 and 2008 growing seasons. The Farm located in 11º45′ lat. N; 30º47′ long. E, 1400 m above sea level. Experimental units were arranged in split-split plots based on randomized complete blocks with three replications. Main plots consisted of (G1): establishing a mixed vegetation of *Vicia panunica* and *Hordeum vulgare* and (G2): control (No green manure), as green manure levels. Also, five strategies for obtaining the base fertilizer requirement including (N1): 20 $t.ha^{-1}$ farmyard manure; (N2): 10 $t.ha^{-1}$ compost; (N3): 75 $kg.ha^{-1}$ triple super phosphate; (N4): 10 $t.ha^{-1}$ farmyard manure + 5 $t.ha^{-1}$ compost and (N5): 10 $t.ha^{-1}$ farmyard manure + 5 $t.ha^{-1}$ compost + 50 $kg.ha^{-1}$ triple super phosphate were considered in sub plots. Four levels of biofertilizers consisted of (B1): *Bacillus lentus* + *Pseudomonas putida*; (B2): *Trichoderma harzianum*; (B3): *Bacillus lentus* + *Pseudomonas putida* and *Trichoderma harzianum*; and (B4): control (without biofertilizers) were arranged in sub-sub plots.

The G1 plots were planted with green manure comprise of vetch (*Vicia panunica*) and barley (*Hordeum vulgare*) with equation portion on 15 October 2007 (in the rows 10 cm apart). On April 10th 2008, these green manures were either incorporated into the soil with a hand-hoe in the manner of a chisel plough. Three soil cores from the tillage zone (0-15 cm) of each plot were collected and routine soil test analysis determined by the Dahnke and Olsen [8] soil test method (Table I). The farmyard manure and compost were also analyzed for chemical and nutrients properties (Table II).

TABLE I
PHYSICAL AND CHEMICAL SOIL CHARACTERISTICS BEFORE STARTING THE EXPERIMENT

EC ($ds.m^{-1}$)	pH	Sand	Silt	Clay	Total nitrogen	Saturated humidity	Available phosphorus	Available potassium
		(%)					(ppm)	
1.2	7.4	36.8	35.7	27.5	0.09	38	9.2	255

TABLE II
CHEMICAL CHARACTERISTICS OF FARMYARD MANURE AND COMPOST APPLIED TO THE SOIL

Characteristic	pH	N	P	K	Ca	Mg	Zn	Cu
		(%)			(ppm)			
Farmyard manure	7.45	0.47	0.49	0.31	745	1100	2	25
Compost	7.2	0.7	1.15	0.51	1950	1890	12	295

The chickpea seeds, according to arrangement of sub-sub plots treated with *Trichoderma harzianum* isolate T39, *Bacillus lentus* isolate P5 and *Pseudomonas putida* isolate P13. Also, *Mesorhizobium sp.* cicer strain SW7 was added to all the treatments. Chickpea seeds planted On 25 April 2008 and harvested on the 75th day after sowing. The nitrogen and phosphorus content of shoot and matured seeds was determined by vanado molybdate phosphoric acid yellow colour method and Microkjeldhal method, respectively [24]. Also, the potassium content was determined by Flame Photometer model-EEL [3]. The other minerals, such as calcium, manganese, magnesium and iron, were determined with an atomic absorption spectrophotometer (Perkin-Elmer Model 5000) [3]. Seed protein content was determined by measuring the N content with the Microkjeldhal method and multiplying it by 6.25 to express to total protein content [6]. Crude fiber and starch were determined using the methods described by Rong et al [34]. The separation and quantification of Sugar compounds from seeds were carried out by an Agilent 1100 series HPLC system (Agilent, USA), which consisted of a G1311A pump and a G1362A refraction index detector [48]. Seed protein contents were determined by near infrared reflectance spectroscopy, using a Bran Luebbe Infra Alyzer 350. Chlorophyll readings were taken with a hand-held dual wavelength meter (SPAD 502, Chlorophyll meter, Minolta Camera Co., Ltd., Japan) at the flowering stage. At harvest time harvest, grain yield and yield components were evaluated from an area of 2 m × 2.5 m in each sub-sub plot. One hundred grams of harvested mature seeds of chickpea from different treatment were taken in beakers fitted with condensers to avoid evaporation losses during boiling. Distilled water was added in the ratio of 1:4 (w/v) to the beakers. Cooking time was determined by the method of Williams et al [48]. The data collected in this study was subjected to analysis of variance (ANOVA) and means comparison has done using Duncan’s multiple range test (DMRT) [22].

III. RESULTS AND DISCUSSION

A. Leaf Chlorophyll

According to the analysis of variance leaf chlorophyll significantly affected by different soil fertility methods, in such a manner means comparisons showed that green manure significantly increased leaf chlorophyll (Table III). Adding leguminous green manures to the soil produced improved soil nitrogen content through symbiotic associations with Rhizobium bacteria and increased other nutrients during decomposition of organic matter. Regarding to the key role of elements such as nitrogen, iron and magnesium in chlorophyll structure, it seems that supply of these elements by green manure is the main reason for increasing leaf chlorophyll. Means comparison also revealed that simultaneous application of bacterium and fungus to the soil increased leaf chlorophyll significantly (Table 3). Co-inoculation of some *Trichoderma* strains and PSB along with effective *Rhizobium* spp. stimulate chickpea nodulation and nitrogen fixation and provide more nitrogen is offered to the crop [30, 36, 43]. Correlation between nitrogen and chlorophyll content has been reported in many studies [29, 11]. Rajendran et al [32] reported that the amount of chlorophyll increased when the co-inoculation with *Rhizobium* strains and PSB. Comparisons of base fertilizer levels showed that the highest chlorophyll content was obtained from N5 treatment. After N5 treatment, followed by N4 treatment (Table III). Increased leaf chlorophyll content in these treatments was related to more mineral elements such as iron, magnesium and manganese provided by simultaneous application of compost and farmyard manure can be one of main reasons for.

B. *Leaf and Grain Mineral Elements*

Green manure had a significant effect on leaf and grain nitrogen content. Means comparisons specified that incorporating vetch and barley biomass into the soil before chickpea cultivation, increased leaf and grain nitrogen contents by 18% and 7% respectively (Tables III and IV). Nitrogen fixation by vetch, increased soil organic matter and optimized conditions for *Rhizobium* bacteria are the main reasons for increasing nitrogen uptake due to application of green manure. Elfstrand et al [14] reported that green manure application increased nitrogen content of plant. Also findings of Ryan et al [37] indicated that application of vetch as green manure enriched the N in grain and straw. Basal fertilizers had a significant effect on leaf and grain nitrogen content (Tables III and IV), in such a manner the highest leaf nitrogen (5.26 %) and grain contents nitrogen (2744 mg per 100 g) obtained from N5 treatment. The main reason is that compost and farmyard manure can increase N availability to plant due to more nitrogen offered to plant. Hatch et al [18] reported that incorporation of farmyard manure to the soil had beneficial effects of increasing biological nitrogen fixation, dry matter and N yields in red clover. Leaf and grain nitrogen content in N2 treatment are significantly more than of those in N1 and N3 treatments (Table III and IV). Also, biofertilizers had significant effect on leaf and grain nitrogen contents. The highest leaf and grain nitrogen contents were obtained from B3 and B1, respectively (Table III and IV). In fact, the positive interaction between biofertilizers and Rhizobium bacterium caused on increase in biological nitrogen fixation. Rosas et al [35] reported that Phosphate-solubilizing *Pseudomonas putida* can influence the rhizobia-legume symbiosis and increase the number and dry weight of nodules in alfalfa and soybean. El-Komy [13] demonstrated the beneficial influence of co-inoculation of biofertilizers for providing balanced nitrogen and phosphorus nutrition of wheat plants. There is evidence that some *Pseudomonas* species increase nutrient absorption, as N, P and K, in addition to act as biocontrol agents of phytopathogenic fungi and produce phytohormones in the rhizosphere, which promote plant growth [28].

The result showed that different methods of soil fertility had a significant effect on leaf and grain phosphorus contents. The highest leaf and grain P contents were obtained from N5 treatment (Table III and IV). Increasing effect of combined application of compost and farmyard manure on soil enzymic activity such as phosphatase and increase P availability for plant has been reported by El-baruni and Olsen [12]. Triple super phosphate fertilizer (N3) in comparison with compost and farmyard manure significantly increased leaf and grain P contents. Also, application of green manure significantly increased leaf and grain P contents.

TABLE III

EFFECT OF SOIL FERTILITY SYSTEMS ON CHLOROPHYLL AND NUTIENT ACCUMULATION IN CHICKPEA SEED

Treatment	Chlorophyll (Spad reading)	Nitrogen (mg/100g)	Phosphorus (mg/100g)	Potassium (mg/100g)	Calcium (mg/100g)	Magnesium (mg/100g)	Manganese (mg/100g)	Iron (mg/100g)
Green manure								
Vetch + barley (G1)	44.11^{a}	2283^{a}	273.8^{a}	1208.2^{a}	184.9^{a}	4.35^{a}	2.64^{a}	4.42^{a}
No green manure (G2)	41.05^{b}	2140^{b}	268.2^{b}	1196.4^{a}	182.9^{a}	4.2^{b}	2.4^{b}	4.36^{a}
Basal fertilizer								
Farmyard manure (N1)	39.18^{e}	2015^{c}	271.6^{b}	1190.2^{b}	184.1^{a}	4.1^{c}	2.67^{a}	4.39^{a}
Compost (N2)	43.06^{c}	2468^{b}	264.7^{c}	1159.3^{c}	184.6^{a}	4.1^{c}	2.61^{a}	4.09^{a}
Chemical fertilizer (N3)	41.5^{d}	1981^{c}	273.2^{b}	1073.7^{d}	183.4^{a}	4.1^{c}	2.65^{a}	4.14^{a}
Farmyard + Compost (N4)	46.25^{b}	2579^{b}	273.1^{b}	1290.2^{a}	183.8^{a}	4.48^{b}	2.66^{a}	4.57^{a}
Farmyard+Compost+Chemical (N5)	47^{a}	2744^{a}	289.6^{a}	1298.1^{a}	183.5^{a}	4.66^{a}	2.68^{a}	4.6^{a}
Biofertilizer								
PSB[a] (B1)	43.4^{b}	2269^{b}	271.5^{b}	1201^{b}	184.3^{a}	4.32^{a}	2.63^{a}	4.42^{a}
Trichoderma fungi (B2)	43.35^{b}	2289^{b}	266^{c}	1176.3^{c}	183.7^{ab}	4.27^{b}	2.56^{b}	4.35^{a}
PSB + fungi (B3)	44.2^{a}	2410^{a}	279.8^{a}	1232.1^{a}	181.2^{b}	4.34^{a}	2.65^{a}	4.47^{a}
Control (B4)	43.2^{b}	2167^{c}	264.9^{c}	1199.8^{b}	184.5^{a}	4.28^{b}	2.57^{b}	4.36^{a}

Mean values in each column with the same superscript(s) do not differ significantly by DMRT (P = 0.05)

[a] Phosphate Solubilizing Bacteria

TABLE IV
EFFECT OF SOIL FERTILITY SYSTEMS ON SEED COOKING TIME, MINERAL AND ORGANIC COMPOUNDS UPTAKE BY CHICKPEA

Treatment	Leaf nitrogen (%)	Leaf phosphorus (%)	Leaf potassium (%)	Grain protein (%)	Grain crude fiber (%)	Grain starch (mg.kg^{-1})	Cooking time (min)
Green manure							
Vetch + barley (G1)	4.93^{a}	0.31^{a}	2.02^{a}	14.26^{a}	8.19^{a}	155.6^{a}	66.35^{a}
No green manure (G2)	4.18^{b}	0.24^{b}	2^{a}	13.37^{b}	7.85^{a}	153.6^{a}	65.8^{a}
Basal fertilizer							
Farmyard manure (N1)	3.87^{d}	0.24^{c}	1.82^{d}	12.59^{c}	7.78^{c}	156.3^{a}	64.43^{b}
Compost (N2)	4.15^{c}	0.21^{d}	1.80^{d}	15.42^{b}	7.43^{d}	153.3^{b}	64.31^{b}
Chemical fertilizer (N3)	3.17^{e}	0.31^{b}	1.98^{c}	12.38^{c}	9.55^{a}	153.2^{b}	66^{a}
Farmyard + Compost (N4)	4.76^{b}	0.30^{b}	2.03^{b}	16.11^{b}	7.07^{e}	157.2^{a}	62.18^{c}
Farmyard+Compost+Chemical (N5)	5.26^{a}	0.43^{a}	2.41^{a}	17.15^{a}	8.28^{b}	157.5^{a}	62.68^{c}
Biofertilizer							
PSB^{a} (B1)	4.22^{b}	0.31^{a}	1.91^{b}	14.18^{b}	8.12^{a}	154.1^{a}	65^{b}
Trichoderma fungi (B2)	4.24^{b}	0.28^{b}	2^{a}	14.30^{b}	8.07^{a}	154.2^{a}	66.7^{a}
PSB + fungi (B3)	4.53^{a}	0.33^{a}	2.03^{a}	15.06^{a}	7.99^{a}	153.6^{a}	66.8^{a}
Control (B4)	4.22^{b}	0.27^{b}	2.02^{a}	13.54^{c}	8^{a}	152.6^{a}	65.6^{b}

Mean values in each column with the same superscript(s) do not differ significantly by DMRT (P = 0.05)
[a] Phosphate Solubilizing Bacteria

TABLE V
EFFECT OF SOIL FERTILITY SYSTEMS ON SUGARS CONTENT OF CHICKPEA SEED

Treatment	Sucrose (%)	Raffinose (%)	Stachyose (%)	Verbascose (%)	Ciceritol (%)	Total sugar (%)
Green manure						
Vetch + barley (G1)	2.57^{a}	0.64^{a}	1.49^{a}	0.47^{a}	2.39^{a}	7.56^{a}
No green manure (G2)	2.48^{a}	0.62^{a}	1.18^{b}	0.46^{a}	2.35^{a}	7.23^{a}
Basal fertilizer						
Farmyard manure (N1)	1.56^{d}	0.62^{b}	1.35^{a}	0.41^{b}	1.97^{d}	5.94^{e}
Compost (N2)	1.73^{c}	0.61^{b}	1.45^{a}	0.49^{ab}	2.02^{d}	6.37^{d}
Chemical fertilizer (N3)	3.29^{ab}	0.64^{a}	1.35^{a}	0.53^{a}	2.60^{b}	8.1^{b}
Farmyard + Compost (N4)	2.97^{b}	0.61^{b}	1.45^{a}	0.48^{ab}	2.28^{c}	7.71^{c}
Farmyard+Compost+Chemical (N5)	3.42^{a}	0.64^{a}	1.45^{a}	0.54^{a}	2.95^{a}	8.77^{a}
Biofertilizer						
PSB^{a} (B1)	2.50	0.61^{b}	1.36^{a}	0.46^{a}	2.36^{ab}	7.31^{a}
Trichoderma fungi (B2)	2.54	0.64^{a}	1.39^{a}	0.46^{a}	2.32^{b}	7.38^{a}
PSB + fungi (B3)	2.54	0.64^{a}	1.37^{a}	0.46^{a}	2.41^{a}	7.44^{a}
Control (B4)	2.52	0.62^{b}	1.41^{a}	0.48^{a}	2.39^{a}	7.46^{a}

Mean values in each column with the same superscript(s) do not differ significantly by DMRT (P = 0.05)
[a] Phosphate Solubilizing Bacteria

Adding phosphorus of green manure to soil and appropriate condition prepared for PSB are the main reasons for increase of leaf and grain P content in this treatment. Mean comparison showed that combined application of biofertilizers (B3) produced the highest leaf P content (0.33%) and grain P content (279 mg.100g^{-1}). Ability of *Bacillus* sp. to produce organic acid such as gluconic, citric and fumaric acids by under P-limiting conditions may increase the solubility of poorly soluble phosphorus [44]. *Pseudomonas* strain inoculation increased phosphatase activity. Phosphatase could contribute to the mineralization of phytate [46]. Since phosphatases play an important role in nutrient P availability of organic manures and crop residue and phosphates activity and soil P availability appear to complement each other [12], therefore providing P in rhizosphere can increase P uptake by plant. Also, regarding to importance of this element, the increase of P causes stimulating growth and increasing grain yield. Similar report of increase in phosphorus uptake by combined inoculation of *Trichoderma* sp. and PSB were reported by Rudresh et al [36].

Basal fertilizers and biofertilizers had significant effect on leaf and grain potassium contents, but green manure had no significant effect on K content. Combined application of basal fertilizers improved plant nutrition conditions. The highest leaf and grain K contents were obtained from N5 treatment. There is evidence that compost application increase potassium absorption in chickpea seeds [38]. Combined application of biofertilizers produced the highest leaf and grain K contents (Table III and IV). The combined application of compost and seed inoculation with *Pseudomonas* increased the availability and uptake of minerals like P, Mn and K in chickpea plants [38].

Green manure had significant effect on magnesium and manganese contents, but there was no significant effect on grain calcium and iron content. The highest Mg, Mn and Fe contents were obtained from N5 treatment and the highest Ca content was obtained from N2 treatment (Table IV). It seems

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that application of compost causes increased availability of nutrition elements to plant. Sahni et al [38] reported that compost application increased the availability and uptake of minerals like Zn, Mn and Fe in chickpea plants. Combined application of biofertilizers increased nutrition elements contents of grain except calcium (Table IV). These findings are agree with the report of Sahni et al [38]. They have stated that *Pseudomonas* increased the availability and uptake of minerals like Fe and Mn in chickpea plants.

C. Grain Organic Compounds

There was a significant effect of green manure on grain protein content, but no significant differences observed in starch and crude fiber. Result showed that application of green manure increased protein content of seed (Table IV). Biologically nitrogen fixed by legumes is a main benefit of growing green manures. The application of green manures to soil is considered as an effective management practice in any agricultural system due to stimulating soil microbial growth and activity, with subsequent mineralization of plant nutrients [15]. This microbial activity increase biological nitrogen fixation in soil [7] and nitrogen uptake by plant. Correlation between nitrogen and protein content has been reported [1, 11]. Other studies have demonstrated that application of green manure increased grain protein content. There was a significant effect of base fertilizers on protein, crude fiber and starch content of chickpea grain. Protein and starch content of grain were found to be enhanced by the combined application of triple base fertilizer (N5) compared to individual one (Table IV). Co-application of compost and farmyard manure enhanced crude fiber and chickpea seed quality. Result showed that biofertilizers had no significant effect on crude fiber and starch content of grain. Chickpea inoculated with biofertilizers have significantly higher grain protein content. Maximum protein content (%15.06) was observed in the treatment that received a combined inoculation of PSB and *T. harzianum*. Vinale et al [45] reported that *Trichoderma sp*. induced genes were associated with protein metabolism. Jutur and Reddy [25] have also reported positive correlation between PSB and protein content. Green manure had no significant effect on grain sugars content while both biofertilizer and base fertilizers influenced sugar content significantly. Combined application of triple base fertilizer (N5) increased sugars content of grain. Combined inoculation of PSB and *T. harzianum* increased the ciceritol and raffinose (Table V). Content of phosphorus, zinc and other minerals in chickpea plant increased under application of compost, farmyard manure and biofertilizers.

D. Cooking Time

Long cooking time of the legumes grain known as an anti-quality trait [48]. In current study combined application of compost and farmyard manure (N4) decreased cooking time of chickpea grain (Table IV). Also combined inoculation of biofertilizers has increasing effect on cooking time. The longer cooking time requirement could be attributed to its larger seed weight, as seed size governs the distance to which water must penetrate in order to reach the innermost portion of seeds. A significant positive correlation of cooking time with seed weight is reported by Kaur et al [20]. Individual application of chemical fertilizer has a longer cooking time (66 min) and seed weight (20.72 g) compared to individual application of compost and farmyard manure. Chickpea has been observed to be the most difficult to cook among the commonly consumed legumes due to its larger seed size and chemical composition [41]. Differences in gelatinization pattern of the starch and the susceptibility of the cell constituents, notably the protein, to softening may contribute to the overall textural characteristics of the legume [40]. Green manure had no significant effect on cooking time.

E. Yield and Yield Components

Analysis of variance showed that various soil fertility methods and their interactions have significant effects on pod number per plant and number of fertile pods. The comparison of treatments means indicated that green manure increased pod number/plant and number of fertile pods (Table VI). Simultaneous application of compost, farmyard manure and chemical fertilizer produced higher amounts of pod number and fertile pods per plant. Base fertilizers × green manure interaction identified that green manure cultivation along with simultaneous application of compost, farmyard manure and chemical fertilizer (G1N5) produced 72.83 pods per plant and 39.75 fertile pods and showed a significant difference with other treatments (Table VII). Evaluating the green manure × biofertilizers interaction revealed that G1B3 treatment produced the highest pod number per plant (Table VIII). The existence of appropriate amount of moisture and nutrients and the lack of pathogens are the most important factors for pods fertility and seed production. Simultaneous application of compost, farmyard manure and chemical fertilizer significantly increased fertile pod number due to more nutrients provision. It seems that existence of PSB along with green manure due to more availability of nutrients and existence of *Trichoderma* fungus due to decrease of pathogens and stress factors, has increased fertile pod number. Report of Rudresh et al [36] indicating to increased fertile pods per plant under combined application of phosphate solubilizing bacterium and *Trichoderma* spp., agree with the current research results. Base fertilizer and biofertilizer and their interaction had a significant effect on seed number per pod and 100 grain weight. Comparison of green manure and base fertilizer interactions showed that the highest seed number per pod was obtained in G1N5 treatment. Although green manure had no significant effect on seed number, but existence of green manure along with integrated application of fertilizers increased seed number per plant. There is a statistically significant correlation between seed number per plant pod fertility percentage. Rudresh et al [36] emphasized that nutrients availability plays an impartment role in increasing seed number per pod.

TABLE VI
EFFECT OF SOIL FERTILITY SYSTEMS ON GRAIN YIELD AND YIELD COMPONENTS

Treatment	Grain yield (kg.ha^{-1})	Pod number per plant	Fertile pods per plant	Grain number per pod	100 grain weight (g)
Green manure					
Vetch + barley (G1)	1961.1^{a}	45.63^{a}	28.53^{a}	1.090^{a}	20.93^{a}
No green manure (G2)	1785.6^{b}	38.78^{b}	26^{b}	1.073^{a}	20.54^{a}
Basal fertilizer					
Farmyard manure (N1)	969.3^{d}	21.83^{e}	14.88^{e}	1.002^{c}	20.34^{b}
Compost (N2)	1521.1^{c}	32.22^{d}	21.37^{d}	1.100^{b}	20.42^{b}
Chemical fertilizer (N3)	2119.4^{b}	44.87^{c}	29.41^{c}	1.022^{c}	20.72^{b}
Farmyard + Compost (N4)	2147.5^{b}	52.60^{b}	34^{b}	1.031^{ab}	20.28^{b}
Farmyard + Compost + Chemical (N5)	2609.2^{a}	59.72^{a}	36.65^{a}	1.151^{a}	21.3^{a}
Biofertilizer					
PSB^{a} (B1)	1756.1^{c}	39.72^{b}	25.84^{c}	1.083^{b}	20.79^{a}
Trichoderma fungi (B2)	1866.2^{b}	40.79^{b}	27.41^{b}	1.072^{b}	21.15^{a}
PSB + fungi (B3)	2560.3^{b}	57.66^{a}	35.07^{a}	1.144^{a}	21.19^{a}
Control (B4)	1310.7^{d}	30.83^{c}	20.73^{d}	1.028^{c}	19.52^{b}

Mean values in each column with the same superscript(s) do not differ significantly by DMRT (P = 0.05)
[a] Phosphate Solubilizing Bacteria

TABLE VII
EFFECT OF BASAL FERTILIZERS × GREEN MANURE INTERACTION ON GRAIN YIELD AND YIELD COMPONENTS

Green manure	Basal fertilizer	Grain yield (kg.ha^{-1})	Pod number per plant	Fertile pods per plant	Grain number per pod	100 grain weight (g)
Vetch + barley (G1)	Farmyard manure (N1)	1100^{d}	22.41^{c}	13.83^{d}	1.014^{c}	20.37^{a}
	Compost (N2)	1523.7^{c}	32.33^{c}	22^{c}	1.114^{b}	21.43^{a}
	Chemical fertilizer (N3)	2214.2^{b}	53.58^{b}	35.25^{ab}	1.020^{c}	20.75^{a}
	Farmyard +Compost (N4)	2293.3^{b}	47^{b}	31.83^{b}	1.128^{ab}	20.18^{a}
	Farmyard+Compost+Chemical (N5)	2888.5^{a}	72.83^{a}	39.75^{a}	1.193^{a}	20.93^{a}
No green manure (G2)	Farmyard manure (N1)	1053.3^{c}	21.25^{c}	15.93^{d}	1^{c}	19.91^{a}
	Compost (N2)	1618.4^{b}	32.12^{b}	20.75^{c}	1.087^{b}	20.41^{a}
	Chemical fertilizer (N3)	2080.8^{a}	51.62^{a}	32.75^{ab}	1.025^{bc}	20.70^{a}
	Farmyard +Compost (N4)	1945.5^{ab}	42.75^{a}	29^{b}	1.143^{a}	20.07^{a}
	Farmyard+Compost+Chemical (N5)	2330.1^{a}	46.62^{a}	33.56^{a}	1.112^{a}	20.29^{a}

Mean values in each column with the same superscript(s) do not differ significantly by DMRT (P = 0.05)

TABLE VIII
EFFECT OF BIOFERTILIZERS × GREEN MANURE INTERACTION ON GRAIN YIELD AND YIELD COMPONENTS

Green manure	Biofertilizer	Grain yield (kg.ha^{-1})	Pod number per plant	Fertile pods per plant	Grain number per pod	100 grain weight (g)
Vetch + barley (G1)	PSB^{a} (B1)	1991.5^{b}	45.4^{b}	28.13^{b}	1.092^{a}	20.55^{b}
	Trichoderma fungi (B2)	2001.6^{b}	44.1^{b}	28.53^{b}	1.109^{a}	21.60^{a}
	PSB + fungi (B3)	2600.6^{a}	60.9^{a}	36.8^{a}	1.118^{a}	21.65^{a}
	Control (B4)	1321.1^{c}	42.06^{b}	20.66^{b}	1.041^{a}	19.95^{b}
No green manure (G2)	PSB^{a} (B1)	1591.5^{b}	34.05^{b}	23.55^{b}	1.075^{b}	20.83^{a}
	Trichoderma fungi (B2)	1730.7^{b}	37.4^{b}	26.30^{b}	1.035^{b}	21.50^{a}
	PSB + fungi (B3)	2519.9^{a}	54.4^{a}	33.35^{a}	1.170^{a}	21.13^{a}
	Control (B4)	1300.2^{b}	29.6^{b}	20.8^{b}	1.015^{b}	19.10^{b}

Mean values in each column with the same superscript(s) do not differ significantly by DMRT (P = 0.05)
[a] Phosphate Solubilizing Bacteria

Despite the increase in 100 grain weight in N5 compared to N4, there was no significant difference between them. However combined application of compost and farmyard manure in comparison with individual application of them increased 100 grain weight. Application of super phosphate chemical fertilizer and PSB had no significant increasing effect on 100 grain weight. Nitrogen plays an important role in grain filling but it seems that despite of phosphorus high role in plant metabolism, this element has less effect on 100 grain weight than nitrogen. Of course application of biofertilizer increased 100 grains weight in comparison with control treatment. Our results indicate to an interaction between biofertilizers and nitrogen fixation bacteria in chickpea roots. A greater number of nodules and dry weight was registered in soybean and alfalfa under co-inoculation with Rhizobia strains and phosphate solubilizing *Pseudomonas* strains [35].

Chickpea grain yield was affected by different soil fertility systems. All two-way interactions significantly influenced grain yield. An increase of 9% in the grain yield of chickpea was recorded under application of green manure was found effective and (Table VI). Since the highest amounts of grain yield components were obtained from N5B3 treatment, it produced the highest grain yield. Combined inoculation of PSB and *T. harzianum* (B3) significantly increased grain yield. Microorganisms' activity to excrete organic acids and phosphates, could be able to release elements from complexes existent in soil and increasing nutrient availability to plants [36, 25]. Similar reports of increase in yield and nutrient uptake by combined inoculation of Rhizobium and PSB were reported by Alagawadi and Gaur [2] and Rudresh et al [36]. The increase in growth and yield components of chickpea by combined inoculation of Rhizobium, PSB and *T. harzianum* found here may be due to cumulative effects, such as enhanced supply of N and P to the crop in addition to growth promoting substances produced by these organisms. In addition to biocontrol activity of *T. harzianum* against soil borne fungal pathogens [47, 45], the increase in grain yield can be attributed to reduced pathogens. The increase in growth and yield of chickpea could also be related to nutrient supplementation among the inoculated organisms, which might have enhanced their efficiencies like N fixation by Rhizobium, P-solubilization by PSB and effective pathogen suppression by *T. harzianum*. Similarly increased nitrogen fixation by Rhizobium sp. due to phosphorus supplementation was reported [26].

Base fertilizers comparison revealed that N5 treatment had a significant difference with other treatments (Table VI). For justification of this difference it could be stated that parallel to meeting plant need to phosphorus, adding compost and farmyard manure to soil can provide micro elements for plant. Compost applied in the current study has been shown to contain elevated concentrations of micro elements including zinc (Zn). Zinc is one of the elements that chickpea indicates positive response to it [42]. Therefore with view to negative interaction between phosphorus and zinc, providing phosphorus by chemical fertilizer decreases zinc availability but compost offers zinc to plant gradually. Also, it seems that green manure causes improving soil structure and optimizing root growth conditions by providing organic matter and nutrients. Comparisons of interactions (Table VII) showed that in treatment having green manure, adding farmyard manure and compost to chemical fertilizer significantly increased grain yield compared to chemical fertilizer, but in the absence of green manure no significant increase occurred in grain yield. Simultaneous application of biofertilizer and green manure also significantly increased grain yield. At last, G1N5B3 treatment is introduced as the superior treatment regarding to grain yield.

IV. CONCLUSION

According to results of various quantitative and qualitative characteristics of chickpea like as yield, yield components and minerals and organic compound of grain, the G1N5B3 treatment could be suggested as superior treatment in this study. Since this treatment seems to be cost efficient and environmentally sound therefore could allocate our agro ecosystem into sustainable agriculture. The more ecological approach to soil management has come from the sustainable development agenda in which central concern with the maintenance of yield is closely associated with desires to conserve natural resources, including a greater value accorded to maintenance of biodiversity.

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