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Effect of Plant Growth Promoting Rhizobacteria (PGPR) and Planting Pattern on Yield and Its Components of Rice (*Oryza sativa* L.) in Ilam Province, Iran

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Abstract**—**Most parts of the world such as Iran are facing the excessive consumption of fertilizers, that are used to achieve high yield, but increase the cost of production of fertilizer and degradation of soil and water resources. This experiment was carried out to study the effect of PGPR and planting pattern on yield and yield components of rice (*Oryza sativa* L.) using split plot based on randomized complete block design with three replications in Ilam province, Iran. Bio-fertilizer including *Azotobacter*, Nitroxin and control treatment (without consumption) were designed as a main plot and planting pattern including 15 × 10, 15 × 15 and 15 × 20 and the number of plant in hill including 3, 4 and 5 plants in hill were considered as a sub-plots. The results showed that the effect of bio-fertilizers, planting pattern and the number of plants in hill were significant affect on yield and yield components. Interaction effect between bio-fertilizer and planting pattern had important difference on the number spikelet of panicle and harvest index. Interaction effect between bio-fertilizer and the number of plants in hill were significant affect on the number of spikelet per panicle. The maximum grain yield was obtained by inoculation with Nitroxin, planting pattern of 15 × 15 and 4 plants in hill with mean of 1110.6 $g.m^{-2}$, 959.9 $g.m^{-2}$ and 928.4 $g.m^{-2}$, respectively.

Keywords**—**Bio-fertilizer, Grain yield, Planting pattern, Rice.

I. Introduction

RICE (*Oriza Sativa* L.) is one of the strategy crop in Iran and it is the most important source of food to people after wheat [1]. The usage of reinforcing materials and new techniques are the most important ways to increase rice production. Bio-fertilizers are natural inputs that can be used as supplementation or replacement of chemical fertilizers in sustainable agriculture [2]. Evaluation of growth indexes has the most importance to analysis effective factors in grain yield and they can help determine the stages of plant growth to evaluate product by quantitative description of growth and development. Planting pattern and plant density are factors that can affect on growth indices, so study on the effect of plant density and planting pattern on plant growth can help us to analyze the grain yield [3]. Also it can lead to increase in production and quality [4]. The results showed that effect of PGPR were significant on plant height, stem diameter, head length, the number of tiller and dry weight of rice [5]. It is seems that increasing in plant growth is by reason of uptake of macro and micro elements by plant and production of hormones [6]. Guenady et al. [6] demonstrated that the increase in dry matter production due to better absorption of essential nutrients such as nitrogen and phosphorous, result in improvement of root development. Given that rice cultivation spread in Ilam province and so far there is any new research about PGPR and planting pattern in this region as for, therefore, this experiment was carried out to effect of PGPR and planting pattern on grain yield and associated traits of rice in Ilam province, Iran.

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II. Materials and Methods

A. Site Description

The present experiment was done as a split_split plot based on randomized complete block design with three replications in Ilam province, Iran during 2012-2013 cropping season.

B. Experimental Details

The experimental factors consisted of bio-fertilizer as a main plot with three levels (*Azotobacter*, Nitroxin and control treatment without consumption fertilizer) and planting pattern (sub_plot) including planting pattern of 15×10, 15×15 and 15×20 and the number of plants in hill (sub_sub_plot) including 3, 4 and 5 plants in hill. Analysis of sail is presented in Table I. The sowing date was July 11, 2013.

TABLE I
Characteristics of Soil

Soil properties	Unit	Value
Carbon Organic	%	0.84
Salinity	ds/m	3.2
P	ppm	280
pH	-	7.73
N	%	0.08
P	ppm	7

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Coinciding with of ear emergence, fertilization operation was done and *Azotobacter* and Nitroxin added to soil.

C. Crop Sampling and Calculation

The four middle rows used for sampling and the two outside rows were considered as border rows. The number of fertile grains in panicle, the number of spikelet in panicle, 1000-grain weight, biological yield, grain yield and Harvest index (proportion of grain yield to biological yield) were accurately measured.

D. Statistical Analysis

Analysis of variance (ANOVA) was done using MSTAT-C software. Mean comparison was also conducted with LSD test.

III. Results and Discussion

A. The Number of Fertile Grains in Panicle

The analysis of variance showed that the effects of bio-fertilizer, planting pattern and the number of plants in hill were significant affected on the number of fertile grains per panicle, but their interaction effect had no significant on this trait (Table II). The highest and lowest the number of fertile grain per panicle was observed by Nitroxin and control treatment, respectively (Fig. 1). In planting pattern treatment the highest and lowest the number of fertile grains per panicle was observed in planting pattern of 15×15 and 15×10 (Fig. 2). Regarding The effect of the number of plant in hill, the highest and lowest the number of fertile grains per panicle was obtained from 4 and 3 plants in hill, respectively (Fig. 3). Probably with increasing in nitrogen fixation by bacteria and transmission of nitrogen to panicles, cell division and production of florets per panicle increased so the number of grains per panicle increased.

Soleimanzadeh et al. [7] showed that *Azotobacter* and different levels of nitrogen fertilizer had a significant effect on the number of grain in sunflower. Bostani [8] demonstrated that the number of grains per panicle increased based on density of 350 plants.m^{-2}. Kheradmand [9] reported that plant density had a significant effect on the number of grains. spike^{-1} in barley crop.

TABLE II
Analysis of Variance (Mean Square) of the Experimental Treatments on the Yield of Rice

S.O.V	d.f	The number of fertile grains per panicle	The number of spikelet per panicle	1000 grain-weight	Biological yield	Grain yield	Harvest index
Rep	2	0.086ns	6.116*	9.042 ns	13191070**	30220**	14.548*
Bio-fertilizer (B)	2	11.012**	67.051**	3912.236 **	23519982**	252515**	1.478**
Eror B	4	0.086	1.529	17.243	182023	347	0.866
Planting pattern (P)	2	17.648**	40.200**	726.396 **	10872852**	64703**	1.707**
B*P	4	4.159**	0.140ns	47.344 ns	128320ns	125ns	0.853**
Eror B	12	0.078	1.871	18.551	159852	762	1.029
Number of plants in hill (N)	2	1.367**	5.401**	126.581 **	1263835**	6570**	0.731**
B* N	4	0.578*	0.055ns	13.880 ns	96652ns	27ns	0.334ns
P*N	4	0.227ns	0.529ns	6.130 ns	66349ns	397ns	0.416ns
B*P*N	8	0.296ns	0.117ns	3.781 ns	57818ns	59ns	0.283ns
Residual	36	0.199	1.197	15.433	65422	458	0.421
CV (%)	-	8.7	4.7	4.48	4.92	4.17	6.48

*, ** and ns: respectively, indicating no significant difference in levels 1 and 5% probability of error and the lack of significant differences.

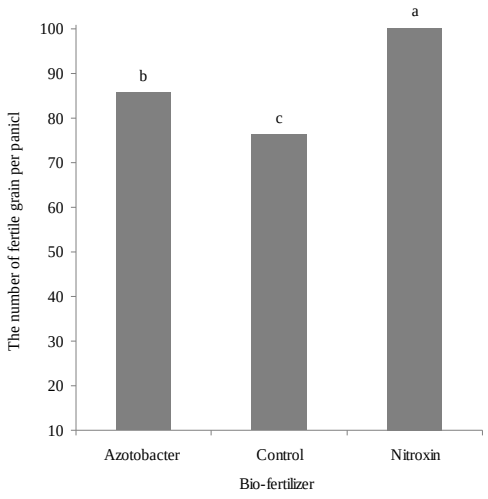

Fig. 1 Effect of bio-fertilizer on number of fertile grains per panicle

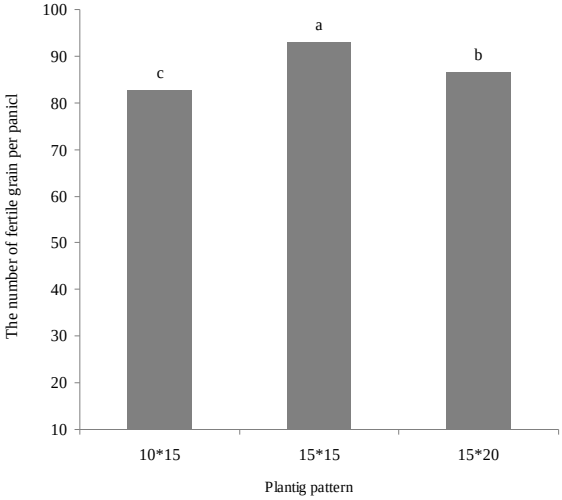

Fig. 2 Effect of planting pattern on number of fertile grains per panicle

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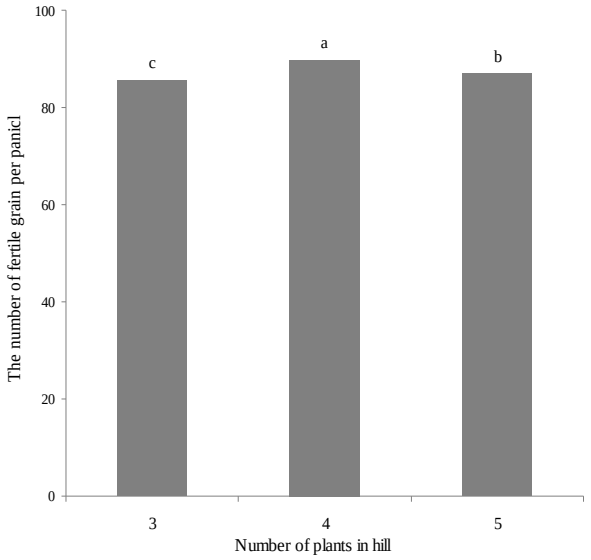

Fig. 3 Effect of number of plants in hill on number of fertile grains per panicle

B. The Number of Spikelet per Panicle

The analysis of variance showed that the effects of bio-fertilizer, planting pattern, the number plants per hill and interaction effect between bio-fertilizer and the number plants in hill were significant on the number spikelet per panicle, but interaction effects of other treatments were no significant on this trait (Table II). The results showed that Nitroxin significantly increased the number spikelet per panicle (Fig. 4). Also results showed that the highest and lowest the number of spikelet per panicle belonged to plants that cultivated by planting pattern of 15 × 15 and 10 × 15, respectively (Fig. 5). Regarding the effect of number of plants in hill the highest and lowest the number of spikelet per panicle was observed in 5 and 3 plants treatment, respectively (Fig. 6).

The interaction effect between bio-fertilizer and planting pattern were significant effect on the number of spikelet per panicle, so that the highest the number of spikelet per panicle value belonged to Nitroxin treatment and planting pattern of 15 × 15 (Fig. 7).

Also the interaction effect between bio-fertilizer and the number of plant in hill were significant effect on the number of spikelet per panicle so that highest the number of spikelet per panicle obtained from Nitroxin and 4 plants in hill treatment (Fig. 8). Sarige et al. [10] found that the nitrogen supply from various sources increased the number of spikelet per panicle.

Kheradmand [9] reported that the maximum the number of panicle in rice obtained from middel density. Rajabzadeh [11] reported that the number of spikelet per panicle increased in different plant densities.

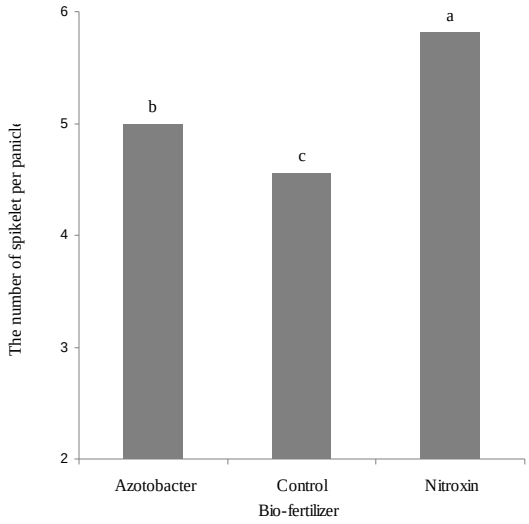

Fig. 4 Effect of bio-fertilizer on number of spikelet per panicle

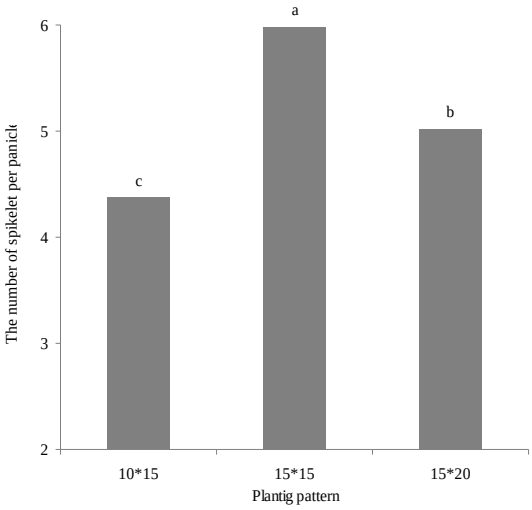

Fig. 5 Effect of planting pattern on number of spikelet per panicle

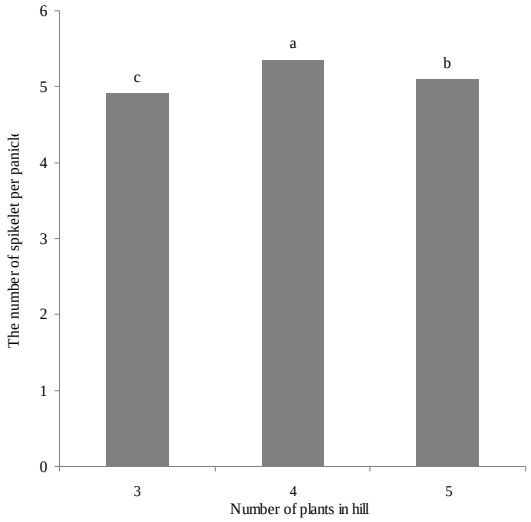

Fig. 6 Effect of number of plants in hill on number of spikelet per panicle

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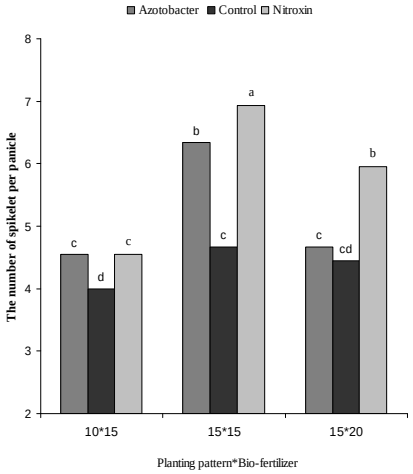

Fig. 7 Effect of bio- fertilizer and planting pattern on number of fertile grains per panicle

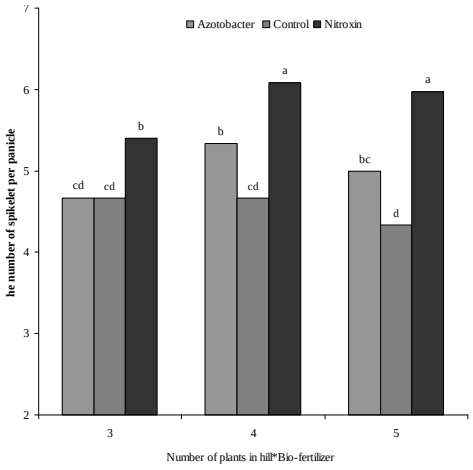

Fig. 8 Effect of bio-fertilizer and number of plants in hill on number of fertile grains per panicle

C. 1000-Grain Weight

The analysis of variance showed that effects of bio-fertilizer, planting pattern and the number of plants in hill were significant effect on 1000-grain weight (Table II). But the interaction effects between them were no significant on 1000-grain weight. The highest and lowest 1000-grain weight was observed by Nitroxin and control treatment, respectively (Fig. 9). About planting pattern between plants the highest and lowest 1000-grain weight was obtained from planting pattern of 15×15 and 15×10, respectively (Fig. 10).

The highest 1000-grain weight was observed in 4 plants in hill (Fig. 11). Rajai et al. [12] showed that inoculation of different strains of *Azotobacter* had a significant effect on 1000-grain weight of wheat crop. Kheradmand [9] stated that plant density had a significant effect on 1000-grain weight on barely**.** Bio-fertilizers improved photosynthesis maybe by increasing water and nutrients absorption leading to produce more assimilate and improvement of plant growth, thus 1000-grain weight increased as compared to non-inoculation treatment [13].

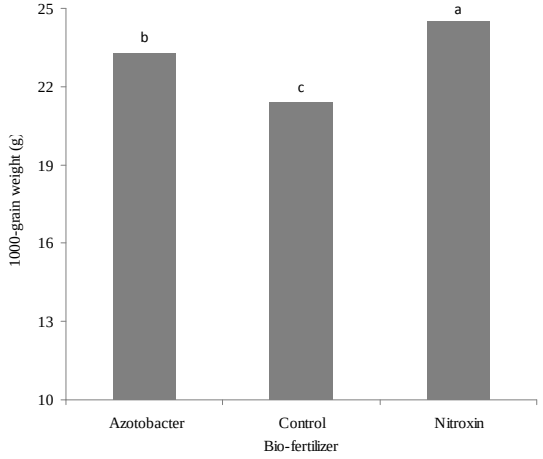

Fig. 9 Effect of biologic fertilizer on 1000-grain weight

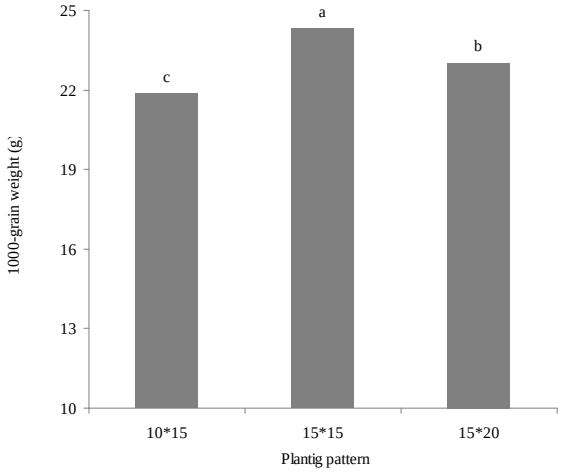

Fig. 10 Effect of planting pattern on 1000- grain weight

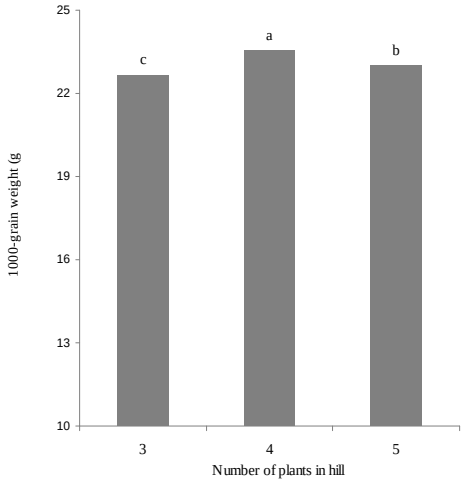

Fig. 11 Effect of number of plants in hill on 1000- grain weight

D. Biological Yield

Analysis of variance showed that the effects of bio-fertilizer, planting pattern and number of plants in hill were statistically significant effect but the interaction effect of other treatments were no significant on this trait (Table II). The

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highest and lowest biological yield was observed in Nitroxin and control treatment, respectively (Fig. 12).

Regarding to planting pattern the highest biological yield obtained from planting pattern of 15×15 treatment (Fig. 13). About the number of plants in hill, the highest biological yield observed in 4 plants in hill with mean of 5398 $g.m^{-2}$ (Fig. 14). Probably due to application of Nitroxin, increased uptake of nutrient at different parts of plant such as leaves, stems and spike; so, total dry matter yield increased. Taherkhani et al. [14] stated that the highest rates of dry matter of bean crop obtained by inoculation with PGPR. Zahir et al. [15] and Fulchirri [16] revealed that production of auxin and gibberellic acid by PGPR (*Azotobacter* and *Azospirillum)* increased crop growth. Kheradmand [9] stated that different plant densities had significantly effect on biological yield in barley. Blaser [17] showed that the maximum dry matter of maize obtained from plant density of 98800 $plants.ha^{-1}$.

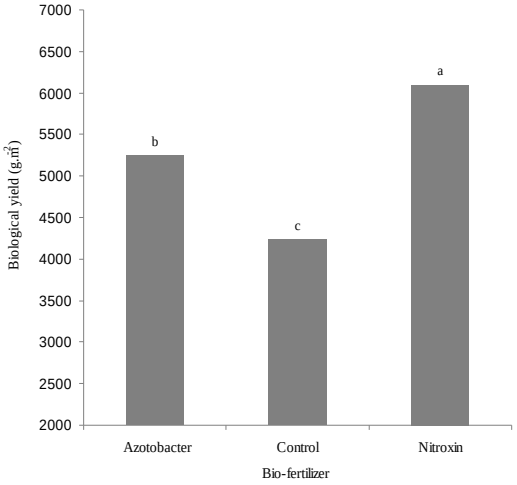

Fig. 12 Effect of bio-fertilizer on 1000-grain weight

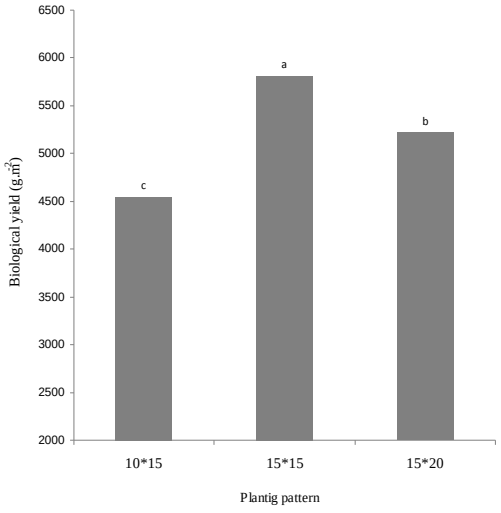

Fig. 13 Effect of planting pattern on 1000-grain weight

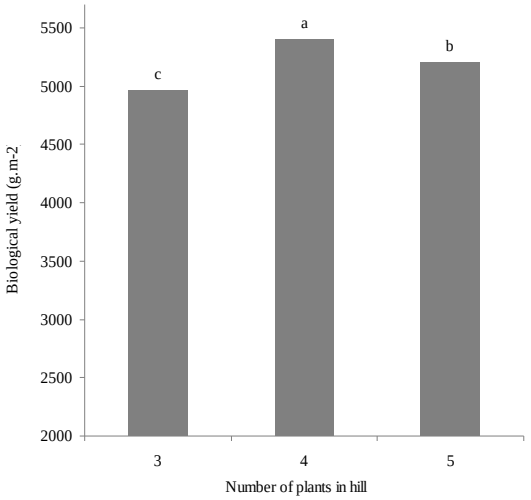

Fig. 14 Effect of number of plants in hill on 1000-grain weight

E. Grain Yield

The results showed that the effects of bio-fertilizer, planting pattern and the number of plants in hill were significant effect on grain yield (Table II). The highest grain yield obtained from application of Nitroxin treatment (Fig. 15).

Also the highest grain yield observed in planting pattern of 15×15 (Fig. 16). Regarding to the number of plants in hill the maximum grain yield was obtained from 4 plants in hill (Fig. 17). Ahmad et al. [18] indicated that increasing grain yield was due to increased metabolic activities and production hormone by bacteria (bio-fertilizer of Nitroxin).

Board [19] reported that increasing plant population per unit can increase grain yield through increasing leaf area index. In fact, leaf area index determines ability to plant for absorbing light for photosynthesis and grain yield. These results are agreement with those obtained by Naseri and Mirzaei [13], Naseri et al. [20] their believed that the highest production of grain yield belonged to inoculation with *Azotobacter* in safflower and rapeseed which under normal conditions, respectively.

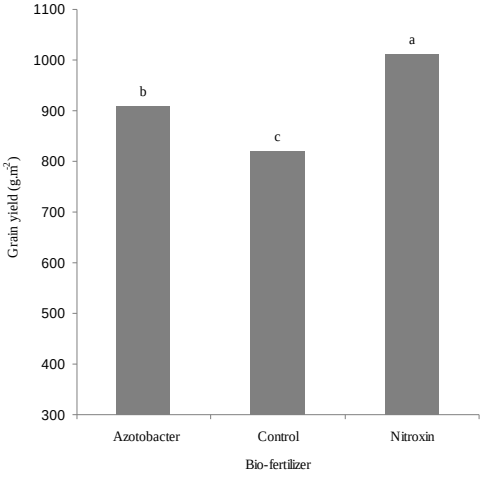

Fig. 15 Effect of bio-fertilizer on grain yield

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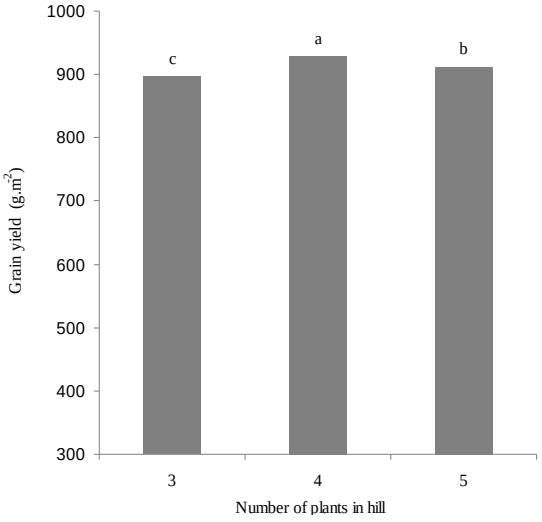

Fig. 16 Effect of number of plants in hill on grain yield

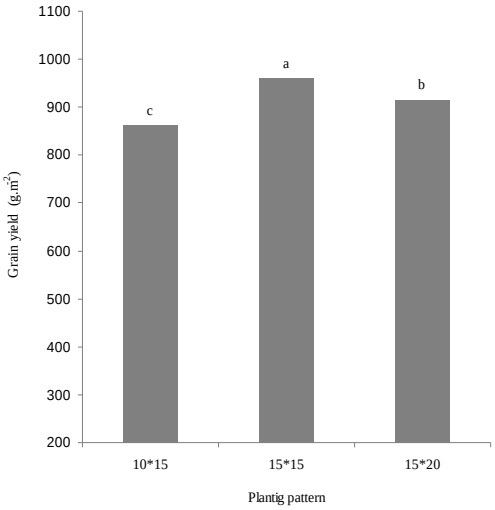

Fig. 17 Effect of number of plants in hill on grain yield

F. Harvest Index (HI)

The results showed that effects of bio-fertilizer, planting pattern and the number of plants in hill were significant on HI (Table II). The highest HI obtained from Nitroxin treatment (Fig. 18). About planting pattern, the highest HI observed in 15×10 and the lowest HI obtained from planting pattern of 15×15 treatment (Fig. 19). Regarding the effect of the number of plants in hill the highest observed in 4 plants in hill that different between them was statistically significant (Fig. 20). The interaction effect between bio-fertilizer planting pattern were significant effect on HI (Table II). The highest HI was achieved in panting pattern of 15×10 and control treatment (Fig. 21). Similar result reported by Bahamin [21], his reported that Nitroxin treatment had more HI to control treatment. Probably one of reasons for decreasing on HI in application of bio-fertilizer (Nitroxin and *Azotobacter*) is due to further increase in biological yield.

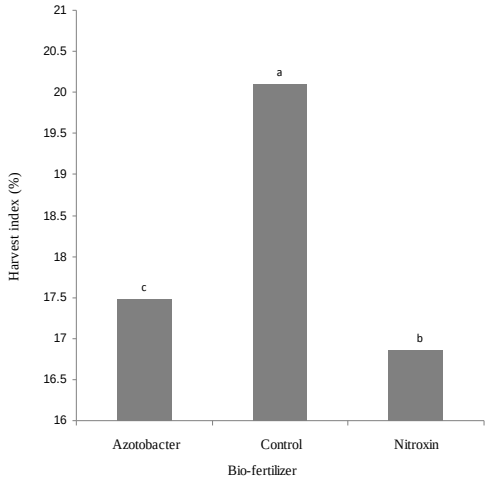

Fig. 18 Effect of bio-fertilizer on harvest index

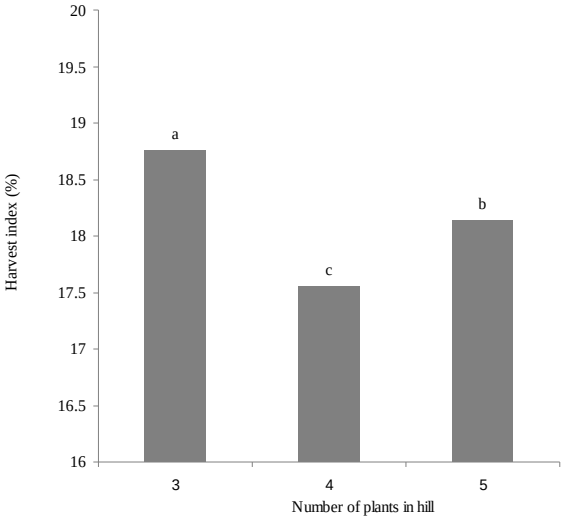

Fig. 19 Effect of number of plants in hill on harvest index

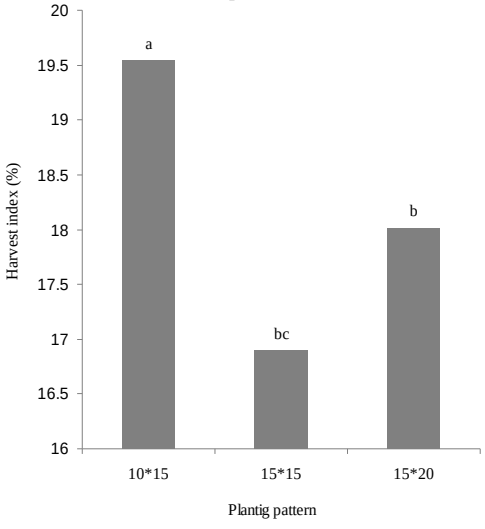

Fig. 20 Effect of number of plants in hill on harvest index

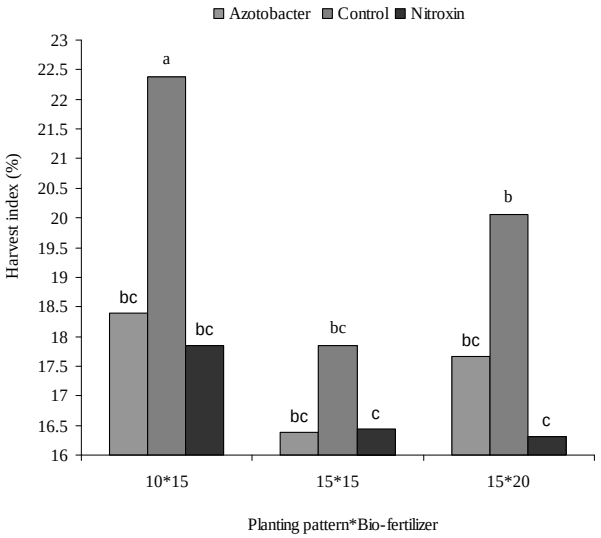

Fig. 21 Effect of bio-fertilizer and planting pattern on harvest index

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