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# Effects of non-chemical and chemical fertilizers on potato (*Solanum tuberosum* L.) yield and quality

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**In order to investigate the effects of natural and chemical fertilizers on yield and quality of potato, a study was conducted at the Agricultural Research Farm of Razi University, Kermanshah, Iran. The experiment was a factorial with three factors arranged in a randomized complete block design with four replications. The first factor was tuber inoculation with Nitragin biofertilizer (a combination of *Azotobacter* species and *Azospirillum* species) at two levels: non inoculated and inoculated. The second factor was HB-101 (a completely organic natural extract) with three levels: non sprayed, one time and two times sprayed onto the potato foliage during the growing season. The third factor was chemical urea fertilizer with two levels: non-used (0) and used at rate of 500 kg/ha. The results showed that the factors had significant effects on tuber yield, tuber weight, the number of tuber per plant, biological yield, harvest index, and tuber nitrate content of potato. The highest tuber yield and the number of tuber per plant were obtained when the tubers were inoculated with Nitragin; urea was used and HB-101 was sprayed two times. Moreover, the lowest tuber nitrate content was obtained when HB-101 was sprayed two times and the tubers were inoculated with Nitragin biofertilizer. It is concluded that integrated application of natural and biological fertilizers along with urea can be useful to enhance potato yield and quality.**

**Key words:** Biofertilizer, HB-101, Nitragin, potato, quality, yield.

## INTRODUCTION

The importance of potato (*Solanum tuberosum* L.) as one of the world's major staple crops is increasingly being recognized, because it produces more dry matter and protein per hectare than the major cereal crops. The nutritional value of potato tubers is a key factor for its progressive production, along with the economic benefits that potato cultivation can bring to developing countries (Van Gijessel, 2005; McGregor, 2007). Besides being an economical and nutritious food source, potatoes also have medicinal properties. A potato tuber is anti-spasmodic, mild anodyne, digestive remedy, diuretic, and emollient. Moreover, potato is a good medicine for stomach ulcer, duodenum ulcer, and stomach acidity.

However, potato growers in Iran usually use very high levels of chemical nitrogen (sometimes more than 1 ton.ha$^{-1}$).

This can lead to the reduced crop quality and the increased environmental pollution (Local information). Ju et al. (2009) reported that total nitrogen losses (including $NH_3$ volatilization, denitrification, and leaching from the soil profile) increased significantly with increasing nitrogen inputs, indicating high environmental costs were caused by exceeding optimum nitrogen fertilizer rates. The over application of nitrogen also represents an unnecessary economic expenditure for farmers. Only by reducing nitrogen fertilizer inputs can degraded environments be gradually restored, enhanced, and protected (Ju et al., 2009). For a sustainable agricultural system, it is imperative to utilize renewable inputs which can maximize the ecological benefits and

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minimize the environmental hazards (Vance, 1997). Extensive use of chemical table fertilizers cause environmental pollution ecological damage and increased production cost (Ghost and Bhat, 1998; Gerber et al., 2005; Mitsch and Day, 2006). To reduce pollution, restoration of land and wetlands, and excessive use of non renewable resources such as petroleum, which are used for the chemical fertilizers production, an alternative method must be developed. For this reason, environmental friendly products such as natural and biological fertilizers can be used to improve soil fertility and plant growth and reduce environmental degradation. Biological fertilizers, which are called biofertilizers, may be used to maintain and improve soil fertility (Dobereiner, 1997). In recent years, they have emerged as a promising component of integrated plant nutrient management system (IPNMS). Biofertilizers are products containing living cells of different types of microorganisms, which have the ability to convert nutritionally important elements (N, P, etc) from unavailable to available form through biological process, such as N fixation and solubilization of phosphate rock (Narula et al., 2000; Sahu and Jana, 2000; Cakmakc et al., 2001; Vessey, 2003). It is well known that these microorganisms, mostly those associated with the plant rhizosphere, are able to exert a beneficial effect upon plant growth and their important role as biofertilizers in crop production systems has been reported in several studies (Cakmakc et al., 2001; Yue et al., 2007; Singh et al., 2005; Cecilia et al., 2004; Suneja and Lakshminaraya, 2001). According to Tyagi et al. (1999), application of biofertilizers can not only reduce chemical fertilizer consumption by 20 to 50%, but can simultaneously increase the crop yield by 10 to 20%.

Asymbiotic N2 fixing bacteria, which live in the rhizosphere often increase yields of cereals and other crops (Reinhold and Hurek, 1989). Many bacterial species were identified to have N2 fixing properties including *Azotobacter* species, *Azospirillum* species, *Beijerinckia* species, etc (Kennedy and Tchan, 1992; Reis et al., 1994). Both *Azospirillum* spp. and *Azotobacter* spp. help in nitrogen fixation and they also produce some growth promoting substances like indole acetic acid (IAA) and gibberellins (GA). However, the information available is very scarce on the beneficial role of biofertilizers, particularly *Azospirillum* and *Azotobacter* on yield and quality of potato.

HB-101 is a natural fertilizer that is used as a growth promoter for plants, flowers, and crop production. It is an organic extract manufactured entirely from renewable resources and without the use of chemicals, serves as a nutrient and vitalizer for the plant itself while reducing the demand for costly chemical fertilizers. However, we could not find any report on the effect of HB-101 on yield and quality of potato. This study has been carried out to evaluate the effect of integrated application of natural, biological, and chemical fertilizers on potato yield and quality.

## MATERIALS AND METHODS

The experiment was carried out in 2010 at the Agricultural Research Farm of Faculty of Agriculture and Natural Resources, Razi University, Iran (latitude 34° 18′ N, longitude 47° 4′ E, altitude 1350 m above sea level). Clay soil containing 0.98% organic matter with 7.9 pH was used. The land was plowed and disked before planting. The crop was planted on the 30$^{th}$ of April, 2010.

The potato cultivar used was Marfona that is extensively grown in the region. The experiment was a factorial with three factors arranged in a randomized complete block design with four replications. The first factor was a tuber inoculation with Nitragin biofertilizer (a combination of *Azotobacter* spp. and *Azospirillum* spp.) at two levels: non inoculated and inoculated. The second factor was HB-101 (a completely organic natural extract) with three levels: non sprayed, one time and two times sprayed onto the potato foliage during the growing season. The third factor was chemical urea fertilizer with two levels: non-used (0) and used at rate of 500 kg/ha. Before planting, potato tubers were immersed in Nitragin solution for 30 to 50 min under dark condition. Each plot consisted of five potato rows of 5 m long with row spacing of 75 cm and with 25 cm between plants on the same row. Chemical urea fertilizer (500 kg/ha, according to the soil test recommendation) was applied at two stages: before planting and flowering. HB-101 solution (1/1,000 v/v) (a purely natural fertilizer that is processed by blending the extracts of cedars, pines, cypress trees, and plantains manufactured by Flora Co. Ltd. Yokkaichi, Japan) was sprayed on the potato plants one time (7 to 10 leaf stage) or two times (7 to 10 leaf and flowering stages). The crop field was weeded as needed throughout the growing season. Plants were irrigated weekly.

To determine potato biological yield (BY), the plants located within a 4 $m^2$ area in each plot were harvested by hand and weighed. Then tubers were separated from the plants, weighed and tuber yield (TY) was recorded in terms of kilogram per hectare. Yield components including the number of tuber per plant (NTP) and tuber weight (TW) were determined on five randomly selected plants in each plot. The harvest index (HI) was calculated according to the following equation:

$$HI = (\text{Tuber yield} / \text{Biological yield}) \times 100$$

Tuber nitrate content (TNC) was determined according to sulfosalicylic acid method (Hlaysova et al., 1970) and was expressed on a tuber fresh weight basis. Data analyses were carried out using Statistical Analysis System (SAS) software (SAS, 2003). Means were compared by Duncan test at the 0.05 level of probability.

## RESULTS

Analysis of variance (data not shown) revealed that all of the traits under study including biological yield (BY), tuber yield (TY), the number of tuber per plant (NTP), tuber weight (TW), harvest index (HI), and tuber nitrate content (TNC) were significantly influenced by urea fertilizer. Nitragin had significant effects on TY, NTP, HI, and TNC, and the effect of HB-101 was significant for NTP, HI, and TNC. Moreover, the significant two-way interaction effects (urea × Nitragin and urea × HB-101) were observed for TY, NTP, HI, and TNC. However, the three-way interaction effect (urea × Nitragin × HB-101) was only

**Table 1.** Means comparison of the urea × Nitragin × HB-101 interaction effect on the tuber yield (kg/ha).

| HB-101 | Nitragin | | | |
|---|---|---|---|---|
| | Inoculated | | Non inoculated | |
| | Urea | | Urea | |
| | Used | Non used | Used | Non used |
| Non sprayed | 43734[bc] | 36721[de] | 33255[d] | 23125[e] |
| One time sprayed | 43753[b] | 39754[d] | 35077[d] | 25655[e] |
| Two times sprayed | 46526[a] | 40816[bc] | 39457[bc] | 26072[e] |

The same letters indicate the insignificant difference at the 0.05 level of probability (Duncan test).

**Table 2.** Means comparison of the urea × Nitragin × HB-101 interaction effect on the number of tuber per plant.

| HB-101 | Nitragin | | | |
|---|---|---|---|---|
| | inoculated | | Non inoculated | |
| | Urea | | Urea | |
| | Used | Non used | Used | Non used |
| Non sprayed | 7.40[bc] | 5.21[e] | 4.8[f] | 2.91[h] |
| One time sprayed | 8.02[b] | 6.55[d] | 6.24[d] | 3.12[h] |
| Two times sprayed | 8.11[a] | 7.22[c] | 6.40[d] | 3.14[g] |

The same letters indicate an insignificant difference at the 0.05 level of probability (Duncan test).

significant for TY and NTP. 101 was sprayed two times (Table 1). Without urea application and Nitragin inoculation, potato tuber yield was notably decreased and HB-101 could not significantly improve this trait, so that the lowest tuber yields were obtained in this condition (Table 1). It means that the application of HB-101 can increase potato yield when the other forms of fertilizers (chemical and biological) are used. However, the effect of the integrated application of Nitragin and HB-101 (two times) in increasing potato yield was higher than urea application alone (Table 1).

The number of tuber per plant and tuber weight, are important yield determining factors, and reflect the extent of tuber development. These yield components were also significantly influenced by the fertilizer treatments. The highest NTP occurred in the treatment in which all kinds of the fertilizers were used (Table 2). One time spray of HB-101 without Nitragin inoculation or urea application had no positive effect on NTP as compared to the control (no fertilizer application) (Table 2). However, BY and TW were only affected by urea fertilizer, so that urea applied at 500 kg/ha increased BY and TW by 31.2 and 21.6%, respectively as compared to the condition in which no urea fertilizer was used (Figures 1 and 2).

Harvest index was also significantly influenced by the fertilizer treatments. The highest HI was observed when the tubers were inoculated with Nitragin and urea was applied (Table 3). However, without urea, Nitragin inoculation alone could not improve potato harvest index. Moreover, Nitragin inoculation along with two times spray of HB-101 notably increased HI as compared with the other treatments (Table 3).

Integrated application of natural products (Nitragin and HB-101) notably reduced tuber nitrate content (Table 4). Although, urea application significantly enhanced TNC, but two times spray of HB-101 could notably overcome the urea effect (Table 4). However, the lowest TNC was recorded when HB-101 was sprayed two times and no urea fertilizer was applied (Table 4).

Correlation coefficients (Table 5) revealed that among the traits under study, NTP had the highest positive and significant correlation with TY. Moreover, the correlations between TY and TW and HI were positive and significant. However, there was no significant correlation between TY and BY (Table 5).

## DISCUSSION

The production of economic yield in any crop generally depends upon the cumulative effects of interactions among several factors such as genetic makeup of crop variety, climatic factors, mineral nutrition, and cultural practices adopted (Ashrafuzaman et al., 2009). The unbalanced and continuous use of chemical fertilizers is leading to reduction of crop yields and in imbalance of nutrients in the soil which has adverse effect on soil health. Therefore, there is an urgent need to reduce the

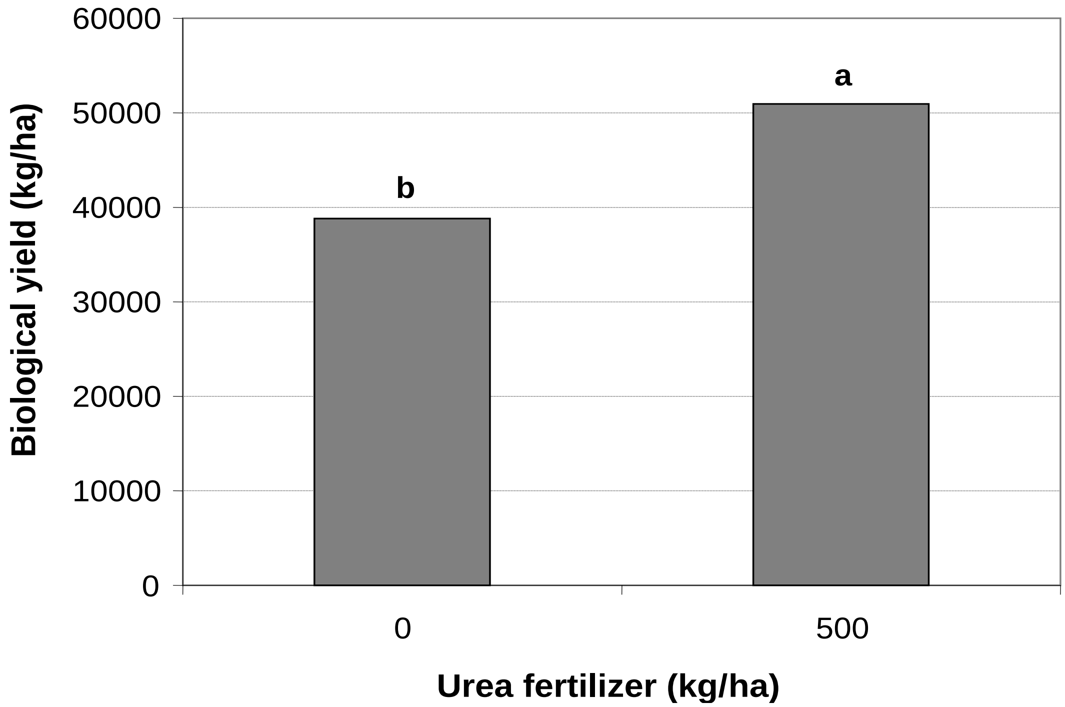


**Figure 1.** Effect of urea fertilizer on potato biological yield. Means followed by dissimilar letters are significantly different based on Duncan test at 0.05 level of probability.

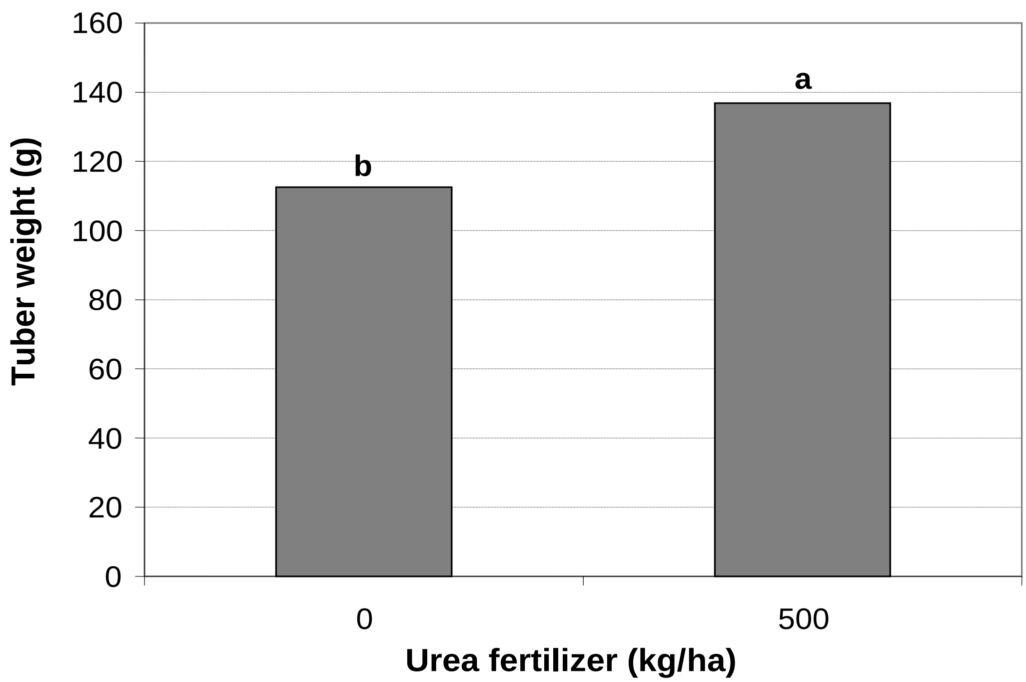


**Figure 2.** Effect of urea fertilizer on potato tuber weight. Means followed by dissimilar letters are significantly different based on Duncan test at 0.05 level of probability.

usage of chemical fertilizers and in turn increase the usage of non-chemical fertilizers which are needed to check the yield and quality levels. Organic nutrients generally facilitate crop rooting, improve water retention capacity, and results in the even distribution of nutrients in soil profile (Husen et al., 2007).

**Table 3.** Means comparison of the Nitragin × HB-101 and Nitragin × urea interaction effects on harvest index (%).

| HB-101 | Nitragin | |
|---|---|---|
| | **Inoculated** | **Non inoculated** |
| Non sprayed | 70.7[d] | 67.3[e] |
| One time sprayed | 77.5[b] | 71.9[c] |
| Two times sprayed | 78.3[a] | 71.6[c] |
| **urea** | | |
| Non used | 65.6[c] | 67.2[c] |
| Used | 83.7[a] | 76.3[b] |

The same letters between two horizontal lines indicate an insignificant difference at the 0.05 level of probability (Duncan test).

**Table 4.** Means comparison of the Nitragin × HB-101 and urea × HB-101 interaction effects on tuber nitrate content (ppm).

| Nitragin | HB-101 | | |
|---|---|---|---|
| | **Non sprayed** | **One time sprayed** | **Two times sprayed** |
| Non inoculated | 35.73[bc] | 46.24[ab] | 28.62[d] |
| Inoculated | 47.24[a] | 31.59[d] | 16.81[e] |
| **Urea** | | | |
| Non used | 34.26[c] | 42.76[ab] | 18.76[e] |
| Used | 47.73[a] | 39.88[ab] | 26.68[d] |

The same letters between two horizontal lines indicate an insignificant difference at the 0.05 level of probability (Duncan test).

**Table 5.** Correlation coefficients between the traits under study.

| Parameter | Tuber yield | Tubers/plant | Tuber weight | Biological yield | Harvest index |
|---|---|---|---|---|---|
| Tuber yield | 1 | - | - | - | - |
| Tubers/plant | 0.98** | 1 | - | - | - |
| Tuber weight | 0.82* | 0.78* | 1 | - | - |
| Biological yield | 0.40 | 0.56 | 0.75* | 1 | - |
| Harvest index | 0.78* | 0.78* | 0.97** | 0.85* | 1 |

* and **Significant at the 0.05 and 0.01 level of probability, respectively.

In this study, tuber inoculation with Nitragin along with two times spray of HB-101 onto the potato foliage led to the increased tuber yield over the treatment in which chemical N fertilizer was applied alone. Overall, integrated application of chemical and non-chemical fertilizers improved potato tuber yield by 39.9% as compared to the chemical fertilizer alone (Table 1). This was mainly due to increase in the number of tuber per plant. Potato biological yield significantly increased when urea was used (Figure 1). Crop biological yield highly depends on the availability of nitrogen. Therefore, nitrogen preparation by urea fertilizer could drastically enhance the biomass produced by the crop. In general, the potato tuber yield and quality depend upon the production of enough photoassimilate and its partitioning in the plant (Frommel et al., 1993). Harvest index is the fraction of the total crop biomass allocated to the economic yield (Williams et al., 1989; Sto¨ckle et al., 1994) and the higher HI indicates the higher crop efficiency to allocate the produced biomass to the tubers.

In our study, harvest index was also affected by natural fertilizers (Table 3). Two times spray of HB-101 along with Nitragin inoculation significantly increased HI as compared to the condition in which these fertilizers were not used. Even at the presence of urea, tuber inoculation with Nitragin notably enhanced potato HI (Table 3).

The increased yield as a result of the biofertilizer application (*Azospirillum* and *Azotobacter*) could be attributed to the effect of growth hormones, like IAA, GA, and cytokinin produced by these microorganisms. This in turn, would have improved assimilation of nutrients and thus yield. According to Dalla Santa et al. (2004), the beneficial effects caused by the biofertilizer inoculation are mainly due to the higher efficiency in the absorption of water and nutrients. This can be attributed to a more developed root system resulted from the produced growth promoter substances by the microorganisms present in biofertilizers. This can lead to the increased soil area explored by the roots. Moreover, these nitrogen fixing microorganisms can significantly increase nitrogen and other nutrients available to the crop. Therefore, the increase in the potato yield may also be attributed to the higher absorption of N and other nutrients which might have favorably affected the chlorophyll content of leaves resulting in increased synthesis of carbohydrates and build up of new cells as reported by Kapulnik et al. (1981) in wheat, sorghum, and Panicum and Chavan et al. (1997) in chilli. El-Sirafy et al. (2006) also found that biofertilizer inoculation increased iron, manganese, zinc, and copper concentrations in crop tissue.

HB-101 especially in combination with the other fertilizers showed the positive effects on the potato traits under study. When HB-101 solution is sprayed onto foliage, the plant obtains necessary nutrients such as nitrogen, magnesium, iron, and silicon. These nutrients are combined with ionized calcium and sodium and absorbed into the leaves cells, thereby, strengthening the cells and increasing photosynthetic efficiency. This results in greener leaves and stronger and healthier plants. In general, it works to improve the growth processes and immune functions of the plant by helping it to attain its original, optimum potentials. However, we did not find any report on the effect of this natural product on potato.

Potato quality was also significantly affected by the fertilizer treatments. In general, application of non-chemical fertilizers led to the reduced tuber nitrate content even in the presence of the urea. So that, integrated use of Nitragin and HB-101 decreased tuber nitrate content by 59.9% when compared with the treatment in which these fertilizers were not applied (Table 4). Application of natural products (Nitragin and HB-101) notably improved potato quality via reduction in the TNC. Among the traits under study, the number of tuber per plant showed the highest positive and significant correlation with tuber yield indicating the important determining effect of this component on potato yield.

There was no significant correlation between the tuber and biological yields (Table 5). This means that the enhanced TY that resulted from the integrated application of the fertilizers was mainly due to the higher allocation of the photoassimilates to the tubers.

## Conclusion

The results indicated that integrated application of the natural and biological fertilizers can notably improve potato yield. Although, to obtain the potential yield of potato, the use of the chemical nitrogen fertilizer is necessary. Potato quality was also positively affected by non-chemical fertilizers even under high chemical nitrogen fertilizer level. Therefore, it is concluded that to produce acceptable potato yield with high quality, integrated use of chemical and non-chemical fertilizers is beneficial.

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