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Changes in morpho-physiological traits and gross income of potato (*Solanum tuberosum* L.) in response to different fertilizers

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Abstract

In order to study the effect of organic and chemical fertilizers on some morpho-physiological traits of potato (cv. Agria), an experiment was conducted based on randomized complete block design (RCBD) with three replications during 2013 in Ardebil region. The fertilizer treatments were included; control (without fertilizer), 100% chemical fertilizer (urea), farm manure, farm manure + 50% urea, Pars Humic Plus organic fertilizer, Pars Humic Plus + 50% urea, Bird Hume organic fertilizer and Bird Hume + 50% urea. Results indicated that farm manure + 50% urea was superior to other fertilizer treatments in terms of all the traits other than chlorophyll content and dry matter percentage. Humic Plus + 50% urea had the highest chlorophyll content (SPAD = 47.34) in the leaf as compared to other treatments; whereas, Bird Hume fertilizer treatment produced the highest dry matter % (27.45).The treatments of farm manure + 50% urea and 100% urea fertilizer indicated the highest tuber yield among the fertilizer treatments. Also the farm manure + 50% urea fertilizer treatment had the highest gross income among the treatments. By increasing the organic fertilizers in the cropping systems the problems of chemical fertilizers will be reduced that is in consistent with sustainable agriculture.

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Introduction

Potato (*Solanum tuberosum* L.) is one of the staple foods for human, with the highest yield among the crops. Moreover, it is the most important nutritive plant after cereals, while ranks fourth crop after wheat, rice and maize in terms of production rate (Högy and Fangmeier, 2008). In Iran, the ever increasing average per capita consumption of potato is over 35 kg; while increasing population and high cost of other food sources inevitably leads to need for higher production of the crop (Khazaei and Arshadi, 2008). Use of chemical fertilizers appears to be the fastest way to overcome food shortage and to maintain soil fertility; however, higher costs of chemical fertilizers used in the recommended amounts, and soil and water pollutions as a result of man-made chemicals, leads to higher demand for organic fertilizers (Brussard and Ferrera-Cenato, 1997). Nevertheless, it is not plausible to entirely remove the chemical fertilizers from the agricultural systems. In this context, use of renewable and natural organic substances beside optimal use of chemical fertilizers prove important in maintaining fertility, structure and biological activity, cation-exchange and moisture holding capacities, and finally improving the physical and chemical properties of soil (Ghosh *et al.,* 2004).

Researchers have reported that application of cow manure into soil increases its microelements and bacterial biomass as compared with chemical fertilizer (Fraser *et al.,* 1988; Change *et al.,* 1991; Amini *et al.,* 2014). Moreover, impact of humic substances on plant growth is well documented. Thanks to the high potential of humic acids, there is a great market for humic acid based products that are commercially available. Generally, humic acid products are available as inexpensive salt solutions such as potassium humate (Fong *et al.,* 2007). Humic acid is used to decrease the negative impacts of chemical fertilizers and some other chemicals present in the soil. Impact of humic acid on plant growth has long been established (Lee and Bartlette, 1976). Gadimov *et al.* (2009) discussed humic substances as the natural technological products with their miraculous effects on crops and concluded that a scientific and practical program is needed to use this technology in the world, particularly in the developing countries. Change *et al.* (1991) reported that commercial products of humic acid were different based on their origin, concentration, production quality, and respond differently to types of soil and agronomic systems. Therefore the aim of this study was to study the effects of different fertilizer treatments on morpho-physiological traits and tuber yield and also gross income of potato to identifying the best fertilizer treatment combination.

Materials and methods

Site description

This study was conducted at field in Ardebil region of Iran in 2013. Prior to the experiment, physical and chemical properties of soil in the study area were measured that are shown in table 1.

Experimental design and field practice

This experiment was conducted based on randomized complete block design with 8 treatments and three replications. Each experimental unit included 4, 5 m-long planting rows. Fertilizer treatments in the experiment were included; control (without fertilizer), 100% recommended chemical fertilizer (urea), farm manure, farm manure + 50% urea, Pars Humic Plus organic fertilizer, Pars Humic Plus + 50% urea, Bird Hume organic fertilizer and Bird Hume + 50% urea. Pars Humic Plus organic fertilizer was applied at 4 kg/ha as mixed with water during 6-8 leaf stage, flowering stage, and tubers expansion stage. Pars Humic Plus organic and biological fertilizer contained 60% humic acid, 15% fulvic acid and NPK of 10:0:10 and all of micronutrients. Bird Hume fertilizer contained 38% humic and fulvic acids, 60% poultry manure and 2% micronutrients and based on its contents it was applied in the basis of 300 kg/ha to soil during plantation. Manure was added and mixed to soil in the basis of 30 ton/ha before planting. As much as 300 kg/ha urea fertilizer was applied to the soil during 6-8 leaf stage, flowering stage, and tuber expansion stage.

Data collection

Final harvest was done during 50% drying of the above-ground organs and after removing the above-ground parts of the plant (10 days before harvesting). Leaf chlorophyll content was measured in upper, lower, and middle leafs during flowering stage by using chlorophyll meter (SPAD) and the mean values were calculated. Several big-, medium- and small-sized tubers were selected and rinsed with both normal and distilled water and dried in order to determine dry matter percentage of tuber. After weighing the tubers, they were cut in thin layers and fully dried by putting them in oven under 75˚C temperature for 48 hours. Then dry weights of the samples were measured and tuber dry matter percentage was calculated by using the following method (Khazaei and Arshadi, 2008):

Percentage of dry matter = tuber dry weight / tuber wet weight × 100.

Statistical analysis

The data subjected to analysis of variance after testing for normality and homogeneity of variance, using MSTATC and SAS. The means were compared using Duncan's multiple range test at $p \leq 0.05$.

Results and discussion

Days to emergence

Results from analysis of variance showed that the fertilizer treatments differed significantly for all the traits (p <0.01). The fertilizer treatments differed significantly for days to greening trait (p <0.01). More specifically, mean comparison (table 2) showed that manure application treatment had the lowest days to greening. However, it did not differ significantly from "farm manure + 50% chemical fertilizer" treatment; whereas, treatments such as control, Pars Humic Plus organic fertilizer and 100% urea fertilizer had the highest days to emergence. It seems that manure application accelerate emergence of the tubers through warming the soil up. It seems that as soil gets warmer by increased manure application to the soil, germination process is accelerated which in turn shortens the period from planting through emergence (Change *et al.*, 1991).

Table 1. Soil characteristics in experimental field.

Texture	pH	EC (ds/m)	Phosphorus (mg/kg)	Potassium (mg/kg)	Total nitrogen (%)
Clay loam	7.94	0.77	27.8	800	0.12

Days to flowering

Results from analysis of variance showed that the fertilizer treatments differed significantly for days to flowering (p<0.01). Mean comparison (table 2) showed that "farm manure+50% urea" treatment had the highest days to flowering; which statistically was not different from 100% urea fertilizer treatment. Control treatment had the lowest days to flowering; whereas "manure + 50% urea fertilizer" treatment and 100% urea fertilizer treatment had the highest days to flowering, which can be attributed to increased leaf and shoot numbers as a result of nitrogen content of the fertilizers.

Table 2. Mean comparison of morpho-physiological traits of potato at different fertilizer treatments.

Fertilizer treatments	Days to emergence	Days to flowering	Days to maturity	Leaf number / plant (50 DAP)	Leaf number / plant (62 DAP)	Leaf number / plant (74 DAP)	Dry matter percentage
Control (without fertilizer)	24.66a	64.66d	131e	51.93c	61.06d	66.46d	26.64ab
Farm manure + 50% urea	19.66c	74a	141.67a	98.26a	107a	126.23a	22.35cd
Humic Plus + 50% urea	24.33a	67.33cd	138.33b	86.16ab	89.26abc	102.26bc	20.76d
Bird Hume	22b	66.33ab	136c	70.03bc	80.60cd	89.90c	27.45a
100% urea	25.33a	70.66ab	142.33a	95.73a	105.26ab	115ab	22.31cd
Humic Plus	24.66a	66.66cd	135.66c	74.63b	87.70abc	96.39c	22.08cd
Bird Hume + 50% urea	22.33b	69.33bc	137.66bc	74.46b	89.60abc	98.5bc	24.32abc
Farm manure	19.33c	69.33bc	136.33cd	73.73b	83.66bc	91.26c	24.05bcd

Different letters in each column represent significant difference based on Duncan's test at 5% probability level. DAP; days after planting.

Days to maturity

Results from analysis of variance showed that the fertilizer treatments differed significantly for days to maturity (p<0.01). Mean comparison (table 2) showed that 100% urea treatment had the highest days to maturity, which was not significantly different from "farm manure + 50% urea" treatment, so that they were classified at the same group. Furthermore, the lowest growth period in terms of this trait belonged to the control treatment. It seems that increased green leaf area as well as increased branch number has a lengthening effect on growth period. Interestingly, availability of nitrogen in abundance, stimulate vegetative growth and delay tuber formation; however, as long as there is no restriction imposed by other environmental factors, it leads to increased tuber growth and increased yield. Moreover, because of accelerated emergence triggered by manure application, and due to exposure to light of leaf area for an extended period; more light is absorbed for photosynthesis and more dry matters are produced (Griffin and Hesterman, 1991).

Table 3. Fertilizer costs and gross income of potato at different fertilizer treatments.

Treatment	Fertilizer cost / ha	Tuber yield (ton/ha)	Gross income = tuber yield × price (Rial)	Gross income fertilizer cost (Ria)
Control (without fertilizer)	0	14.34	143400000	143400000
Farm manure + 50% urea	15600000	35.70	357000000	341400000
Humic Plus + 50% urea	6400000	23.95	239500000	233100000
Bird Hume	2760000	20.28	202800000	200040000
100% urea	3600000	31.25	312500000	3089000000
Humic Plus	2800000	21.73	217300000	214500000
Bird Hume + 50% urea	6360000	25.95	259500000	253140000
Farm manure	12000000	24.46	244600000	232600000

Leaf number per plant

Difference between the fertilizer treatments was found to be significant in terms of leaf number per plant (p< 0.01). More specifically, mean comparison (table 2) showed that there was no significant difference between "manure + 50% urea" treatment and 100% urea treatment, and both produced the highest leaf number; followed by "Pars Humic plus + 50% urea" treatment. Furthermore, mean comparison on leaf number per plant, for 62 days after planting (DAP), showed (table 2) that "manure + 50% urea" treatment was superior to the other treatments in terms of this trait; whereas lowest leaf number per plant belonged to control treatment. Mean comparison on this trait for 72 DAP (table 2) showed that "manure + 50% urea" treatment, with a considerable difference than other treatments, had the highest leaf number per plant; whereas, control treatment produced the lowest leaf number per plant. Chemical fertilizer (urea) and farm manure with their nitrogen content has increased leaf formation in the plant through increased chlorophyll and leaf area of the plant. In contrast with chemical fertilizer, nitrogen in organic fertilizers is released gradually into soil, which may be one of the reasons for slow increase of dry weight of the plant as a result of gradual application of the fertilizer to the soil. In general, application of manures and chemical fertilizers to soil has increased nutrients such as nitrogen in it; this may have an increasing effect on growth of above-ground organs and on leaf area (Beukema and vander Zaag, 1990).

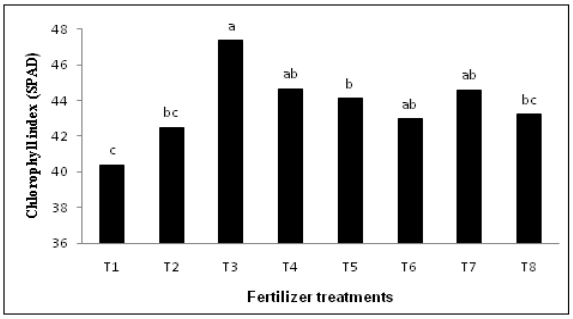

Fig. 1. Effect of different fertilizer treatments on chlorophyll index. Different letters in each column represent significant difference based on Duncan's test at 5% probability level. T1- control (without fertilizer) T2- manure + 50% urea, T3- Pars Humic Plus + 50% urea, T4- Bird Hume, T5- 100% urea, T6- Pars Humic Plus, T7- Bird Hume + 50% urea and T8- Farm manure.

Dry matter percentage

Based on results from analysis of variance fertilizer treatments differed significantly for dry matter percentage (p<0.01). The mean comparison (Table 2) showed that Bird Hume treatment produced the highest dry matter (27.45%), which was not significantly different from the control treatment (26.64%); whereas treatments such as "manure + 50% urea" (22.35%), 100% urea (22.31%), and Humic Plus (22.08%), statistically did not differ significantly from each other and produced the lowest percentage of dry matter. Azizi Agh Ghaleh (2000) reported that increased application of manure led to a decrease in amount of tuber dry matter. Generally, all the factors stimulating growth of the above-ground organs, lead to a decrease in dry matter percentage. In contrast, factors that stimulate tuber formation in potato, increases dry matter percentage in potato (El Sayed Hameda *et al.,* 2011).

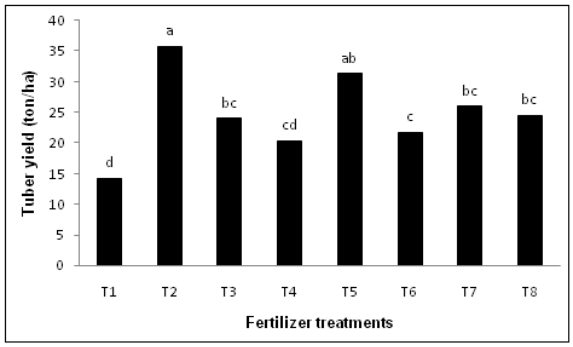

Fig. 2. Effect of different fertilizer treatments on tuber yield of potato. Different letters in each column represent significant difference based on Duncan's test at 5% probability level. T1- control (without fertilizer) T2- manure + 50% urea, T3- Pars Humic Plus + 50% urea, T4- Bird Hume, T5- 100% urea, T6- Pars Humic Plus, T7- Bird Hume + 50% urea and T8- Farm manure.

Chlorophyll index

Results from analysis of variance showed that fertilizer treatments differed significantly for chlorophyll index (p<0.01). The mean comparison showed that "Humic Plus + 50% urea" treatment had the highest chlorophyll index (47.34), followed by Bird Hume (44.63) and then by "Bird Hume + 50% urea" (44.59); they had a significant difference with the control treatment which had the lowest chlorophyll index (Fig. 1). It seems that nitrogen content of Pars Humic Plus organic fertilizer and urea fertilizer has contributed to the formation of chlorophyll molecules which in turn has increased chlorophyll index. Mauromicale *et al.* (2006) and Jongschaap and Booij (2004) also observed a positively significant linear relation between nitrogen availability and leaf chlorophyll content in different potato cultivars. Ferretti *et al.* (1991) reported that effect of humic substance on decreasing chlorophyll content is clear; however, Liu *et al.* (1998) reported that chlorophyll content index is not affected by humic substance.

Tuber yield

Analysis of variance showed that the fertilizer treatments differed significantly for tuber yield per hectare (p <0.01); while mean comparison showed that (Fig. 2) "manure + 50% urea had the highest tuber yield (35.70 ton/ha), which was not so different from 100% urea treatment (31.25 ton/ha). Control treatment produced the lowest (14.34 ton/ha) tuber yield (Fig. 2). Furthermore, application of sufficient nitrogenous fertilizer in early growing season increases leaf area and photosynthetic capacity of plant and produces assimilates. Osaki *et al.* (1992) also emphasize the relation between tuber yield per plant and application of nitrogen in potato. In addition to assimilation rate, proper remobilization and distribution of these substances from leafs to tubers are also among the factors that play a key role in increasing tuber weight per plant (Kazemi, 2003). Using a combination of biological, chemical and organic fertilizers as an alternative to chemical fertilizers can lead to increased tuber yield of potato through creating a balance between soil components and improving rhizosphere conditions, decreasing soil pH (Mohammadi Aria *et al.,* 2010). Moreover, the importance of manure in increasing tuber yield may be down to the fact that it contains some important nutrients; improves the physical and chemical properties of soil, particularly increases the moisture holding capacity of soil and decreases its pH; and subsequently contributes to the absorption of micronutrients (Opena and Portner, 1999). Based on

another report, as the manure application increased from 0 to 60 ton/ha, tuber yield increased by about 35% from 21.56 to 29.01 ton/ha (Lahleghani *et al.,* 2006). Hasandokht (1996) also reported that increase in manure application from 0 through 20 to 30 ton/ha, increased tuber yield of potato by 30% and 47%, respectively. In a research, response of two cultivars against different application amount of nitrogen and manure was studied and based on the results; maximum yield was produced by application of 160 kg nitrogen or 30 ton manure/ha (Hasandokht *et al.,* 1998).

Fertilizer cost and gross income

Based on evaluation of fertilizer cost and gross income of the fertilizer treatments, it can be seen that with respect to higher fertilizer cost per hectare "manure + 50% urea" treatment had the highest gross income as compared to other treatments. The lowest fertilizer cost and gross income were belonged to the Bird Hume organic fertilizer treatment. Although 100% chemical urea fertilizer treatment had lower fertilizer cost than "manure + 50% chemical fertilizer" treatment, and it had a trivial difference with "manure + 50% chemical urea fertilizer" in terms of gross income. Treatments such as Bird Hume organic fertilizer and Pars Humic Plus organic fertilizer had the lowest fertilizer cost and gross income. Although treatments such as "Bird Hume organic fertilizer + 50% chemical urea fertilizer" and "Pars Humic Plus organic fertilizer + 50% chemical urea fertilizer" were almost similar with respect to fertilizer cost per hectare. Based on the data (table 3), one can infer that potato is one of those plants that has high nutritional requirement. This means that by using a combination of organic fertilizers and farm manure with low chemical input to supply its nutrients, it is possible to obtain crop production with high quality with desirable yield and also to achieve higher gross income per hectare (table 3). Ghorbani-Faal *et al,* (2013) and Dabbagh Mohammadi Nasab *et al.,* (2013) reported that Cultural–mechanical management produced the highest gross income among the management treatments.

Conclusion

Results from this study show that "50% of recommended chemical fertilizer +farm manure" treatment improved tuber yield and subsequently increased their yield per unit area more than other treatments. The reason for this was the combining effect of high growth rate of the plant and nutrient supply of the plant by microorganisms present in the organic fertilizers. When humic acid based organic fertilizers are used in potato production, quality of the tubers shows comparatively more improvement. Moreover, application of humic based organic fertilizer and the recommended chemical fertilizer in a proper combination into the soil can improve leaf photosynthesis and increase production of the photosynthetic substances. Similarly, results from this experiment showed that application of organic fertilizers together with half of the recommended chemical fertilizer leads to increased availability of plant's nutritional requirements and increased chlorophyll content of the plant, which in turn leads to high production rate. Also by increasing the organic fertilizers in the cropping systems the problems of chemical fertilizers will be reduced that is in consistent with organic and sustainable agriculture.

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