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Impacts of Nitrogen Fertilizer Sources, Amount and Timing on Yield and Yield Components of Potato

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Abstract

To obtain the optimum N fertilizer amounts, sources and timing for potato, we conducted an experiment in split plot-factorial form based on randomized complete block designs with 3 replicates in Jiroft city, located in the south of Kerman Province, Iran. In this study, we took into account N sources for the main plots and N fertilizer amount and time for the subplots. As to the N fertilizer consumption timings and the levels, T1 stands for the total consumption of N fertilizer during cultivation, T2 for consumption of 1/2 N at cultivation and the remaining 1/2 simultaneous with the beginning of flowering and T3 for of 1/3 N consumption at planting, 1/3 of N consumption coincided with the soil hilling and 1/3 at the same time as flowering; N rates were of the levels R1:150, R2:200 and R3:250 kg/ha. Sources were considered to be of two levels: S1=urea and S2-ammonium sulfate. According to our results, treatments were significantly different with regard to yields so as to obtain the highest yield from R3 treatment consumption at the rate 26.72 ton/ha, which statistically had no particular difference from R2 treatment with a rate of 23.86 ton/ha. In addition, the highest yield was obtained from the time T2 with the rate 30.83 ton/ha and from the source S1 the highest yield was 27.38 ton/ ha. Regarding such results, the highest yield belonged to the treatment R2S1T2.

Keywords**:** Consumption time, Fertilizer, Jiroft, Rate, Tuber

Introduction

Potato is a remarkable crop in its provision of most essential nutrients for humans and can compensate for shortages of food energy. It is ranked the forth after wheat, rice and corn regarding their annual production rate, the second after corn as to the number of food producer countries and the same as wheat and rice in terms of nutritional value Vors(Kord Zanganeh and Amin, 2001). N amount in potato plant organs is at its maximum after carbon, oxygen and hydrogen. Potato is also the first food element to be discussed as for its shortage in soils of arid and semi-arid areas (Houshmand, 2011). Nitrogen is the most essentially important element in plants, playing a central role in soil chemical fertilizers (Reisi and Khaje Pour, 2008) and changing plant composition more than other mineral element (Kord Zangane and Amini, 2001). Due to its role in agricultural production in arid and semi-arid areas, it is necessary to wisely choose the right type and rate of N fertilizer for an optimum harvest (Malakouti, 1996). One kilogram of potato produces about 9700 kg calories and the energy from each potato hectare is 2.5 as much as that obtained from cereals and grain foods (Meshkin et al, 2016). Sufficient consumption of N fertilizers in the earlier days of the growth season contributes to leaf area expansion, rise in plant photosynthesis capacity and production of preserved food. On the one hand, shortage of N early in the growth season may decline yield through its negative effects on tuber growth, but on the other, its excessive application induces aerial organs vegetative growth, delays tubers formation and constrains crop maturity, followed by reduction in the yield and quality. A widespread expansion of leaves, brunches and aerial organs resulting from N over fertilization provokes competition between the aerial organs and the growing tubers for producing preserved foods and this minimizes the plant production efficiency (Reisi and KhajePour, 2008). As Osaki et al. (2012) reported, after using the range of 0 to 300 kg/ha nitrogen, the number of tubers per bush and their size increased. Also, there has been a report on the mean tuber weight with the added nitrogen (Prosba, 2002). Joern (2014) examined different amounts of N fertilizer (0, 75, 112, 168 kg/ha) in the form of ammonium sulfate; maximum yield was obtained with the application of 112 kg/ha nitrogen, particularly when consumed in two stages, cultivation time and tuber formation. Hesterman and Griffin (2003) researched into potato response to N sources and showed that with the application of nitrogen after legumes (green manures or the harvested legume) the total yield of the marketable tuber will rise in the second year. Lots of crops, say, potato, consume and store nitrogen in their leaves for tuber growth (Razaee and Slotani, 2010). In a study, ammonium sulfate and ammonium nitrate raised tuber response to urea; a maximum yield of 22.9 ton/ha occurred when ammonium sulfate was applied at a 5 cm distance above the seed tuber, and a minimum of 19 ton/ha when urea was used at the same distance. However, N sources did not significantly affect tuber weight, number of tuber per square meter and number of stems per square meter (Sharma, 2011). Nitrogen fertilizer timing is a notable factor in determining plants growth rate and responses. N use early in the growth season attracts more sunlight and improves plants photosynthesis and growth (Gathungu and Shibairo, 2018). In another study, different amounts and sources of nitrogen affected the tubers nitrate differently. Maximum nitrate was gained when ammonium and sulfate were applied (Zirrat, 1998). In a further experiment, the use of calcium nitrate as N source led to increases in potato growth and yield (Maier et al, 2002).In a subsequent three-year research 1999-2001 in Behbahan Agricultural Research Station, Khuzestan province, Iran, four levels of 0, 60, 120, 180 kg/ha nitrogen were examined as for their effects on potato Kuzima cultivar. The compound analysis of the results from the above research indicated that consumption of different levels of nitrogen increased yield linearly, being remarkable up to 180 kg/ha pure N consumed; the last level of the consumed pure N was superior to the other levels resulting in a maximum yield when 50% of it was consumed at planting time and the remaining 50% one month after 2001 shooting at the first stage of soil hilling around bushes (Kord Zangene and Amin, 2001). During 1997-1999an experiment was performed evaluating the influences of rates and timings of N fertilizer consumption on potato yield of the in Golmekan Agro-Research Station in Khorasan province, southeast of Iran, with various pure N rates (90, 135and 180 kg/ha) and four times of N application in which T1 stood for the total consumption of N fertilizer at planting, T2 for consumption of 1/2 N during cultivation and the remaining within bushes soil production stage,T3 for the application of 1/3 N at cultivation and the remaining in the bush soil production time period and T4: total consumption of N during the soil hilling stage. The results showed that the highest yield had belonged to the treatment T4T3 (the application of 180 kg/ha N during soil hilling around potato bushes) with the rate 30.69 ton/ha (Rokni, 2017). As Potato is a strategic crop but less studied in the tropical areas of Iran; therefore, this research examined the influences of N fertilizer rates, resources and timings on potato yield in Jiroft city.

Materials and Methods

We performed the experiment in January in 2019 in the Agricultural Research Farm Field of the Islamic Azad University in Jiroft. Jiroft has a warm and semi-humid climate with a longitude of 48.57° and latitude of 35. 28° situated 625.6 m above sea level at 235 km distance from Kerman in the southeastern part with a mean annual rainfall of 130 mm and a mean relative humidity of about 55 to 65%. The treatments were performed via split plot-factorial form with 3 replicates in which time and rates of N fertilizer were used in the factorial form for the subplots and N resources for the main plots. N resources for this study included S1=urea, S_2= ammonium sulfate; N rates were of 3 levels: R1:150, R2:200, R3:250 kg/ha and the times for N application were of 3 levels:T1= the total consumption of N fertilizer during cultivation, T2-consumption of 1⁄2 N at cultivation and the remaining $\frac{1}{2}$ simultaneous with the beginning of flowering and T3 for of % N consumption at planting, $\frac{1}{3}$ of N consumption coincided with soil hilling around bushes and the remaining at the same time as flowering. We used the Konkord cultivar for the research. This medium cultivar of potato has such properties as large oval tubers, fairly shallow eyes, a very good response and high dry matter volume, medium susceptibility to the leaf moth-clothing, immunity to the X virus and resistance to the YN virus(15). We initially removed two composite samples from 0-25 and 25-50 cm depths so as to realize the soil physico-chemical properties, ploughed the piece of land by a plow, then scattered the chemical fertilizers phosphorus and potash onto the surface to be mixed with the soil via a disc. The consumption rates of phosphorus and potash were chosen on the basis of the results from the soil analysis and calculation of 100 kg potash measured in K2O from the source potassium sulfate and 50 kg phosphorus according to $P_2O_5$from triple super-phosphate as the source. After disc process, a leveler was used for making the area flat. After leveling out, we carried out the designed plan, planting on January 1st, 2019 by hand. Each subplot consisted of 4 lines of cultivation, each line of 8 m in length, with rows at 75 cm distance in between and each bush was 25 cm distant from its subsequent one. The main plots had a distance (two cultivation lines) of 1.5 m from each other, the subplots 75 cm-one cultivation line- together with replicates of 2 m distance from each other. Over the growth period, the weeds were twice uprooted by a farm hand and the samples were taken from the 2nd and 3rd lines at a 14-day interval. Omitting marginal effects, the lines were harvested when the leaves were yellow and the tuber skin was not easily peeled by hand. To measure the mean tuber weight and the number of tubers per bush, 5 potato bushes were randomly chosen from each treatment and then analyzed statistically. Data variance was analyzed by the MSTAT-C software and all comparisons were made via the Duncan test at the probable levels of 1% and 5%.

Results and Discussion

Tuber Yield

As to the effects on tuber response, there was a statistically significant difference between treatments of amounts and times of N consumption and between fertilizing sources as well at p=1% (Table 1). But among these treatments the interaction effects on this trait was not significant. Maximum tuber yield resulted from use of urea fertilizer source with a yield of 27.38 ton/ha and its minimum amount was obtained from ammonium sulfate with 19.33ton/ha. Also, the highest yield from T_2 equaled 30.08 ton/ha. The T_3 treatment has provided the essential tools for more dry matter accumulation, including production of a suitable leaf area and more efficient aerial organs. In the T_1 treatment, considering non uptake N into the plant due to its wastage by leaching from the soil in the cultivation-tuber germination interval, since increase in the number of tubers occurs only up until the flowering time of potato, total consumption of N at planting time (T1) causes N to become gradually unavailable so as to expose the plant to N shortage in its later stages of growth until flowering. There has been a report on soil nitrate leaching due to total application of N at planting (Hesterman) and Griffin, 2003). Maximum tuber yield obtained from R_3 equaled 26.72ton/ha. It appeared that N increased the tuber response and more uses of N too maximized the potato crops, having an upward trend regarding an initial use of 150 kg/ha pure N and its rise to 200 kg/ha. Although N application from 200 to 250 kg/ha increased the crop, statistically the two amounts had no significant difference. Likely the excess N rate of more than 200 kg has been less consumed by the plant, ascended or leached. As to Singh and Sood (2014)'s report, after using different amount of pure N fertilizer (0, 60, 120 and 180 kg/ha) the yields of 12.1, 13.4, 26.1 and 28.4 were obtained, respectively. As observed by this study, with increase in N application there is a rise in potato tuber response, similar to the above study. Minimum yield resulted from minimum use of nitrogen and more yields were the direct results of more N application. In other experiments as well tuber response intensified by more N applications to a specific

degree, afterwards no significance response was observed (Gathungue and Shibario, 2018; Houshmand, 2011) .

Table 1: Results for variance analysis of potato measured parameters (square means)

Variation Sources	**Freedom degree**	**Tuber Weight**	**Number of tuber per Bush**	**Number of stem per bush**	**Yield**
Block	2	520.97^{ns}	3.56^{ns}	0.087^{ns}	7.292^{ns}
N source	1	5126.32^{ns}	0.107^{*}	0.019^{*}	876.042^{**}
Error A	2	1364.71	4	0.574	1.681
Fertilizing Time(B)	2	4660.35^{*}	1.202^{ns}	0.116^{ns}	610.542^{**}
A*B	2	4660.35^{**}	4.68^{ns}	0.127^{ns}	58.042^{ns}
Fertilizer Rate (C)	2	2657.77^{**}	1.48^{ns}	0.276^{ns}	238.097^{**}
A*C	4	1637.46^{*}	0.249^{*}	0.234^{ns}	0.597^{ns}
B*C	4	2278.32^{**}	5.161^{ns}	0.134^{ns}	31.097^{ns}
A*B*C	4	3062.94^{**}	2.701^{ns}	0.246^{ns}	17.347^{ns}
Total Error	3o	6.844	6.844	0.327	18.622
Variation Coefficient (./.)		18.35	18.35	21.75	18.47

*and** indicate significance at the probability levels of 1% and 5%, respectively and ns shows non significance.

Number of stem per bush

As table 1 displays, There are significant differences between fertilizer sources treatments at p=5% affecting the number of stems per bush. However, no statistically significant difference was observed between N use rates and timing treatments as for the effect. Maximum numbers of stems per bush arose out of ammonium sulfate source with 1.94 stems and the minimum rate out of urea fertilizer with 1.90. Since Jiroft area soils contain the alkaline PH of 8.2 and the use of ammonium sulfate declines the soil PH in the root zone, it is likely that appropriate conditions are provided for micronutrients uptake and positive response of the potato plant. The highest numbers of stem per bush resulted from T_2 (consumption time) with 2.011 stem and the lowest from T_1 equaled 1.85 (Tables 2 and 3). The highest numbers of stem per bush resulted from T_2 (consumption time) with 2.011 stem and the lowest from T1 equaled 1.85 (Tables 2 and 3). The number of stems per square meter depends on the number of planted tuber eyes per square meter, the soil conditions, the cultivation method and the rate of harm to the tubers; driving factors like tuber size, age and applied cultivar affect number of stem as well (Rezayee and Soltani, 2010). According to some reports, rise in the number of stem induced production of more tubers in it (Lemage and Caeser).Maximum stems arose from R_3 with 2.03 in rate and the minimum rate resulted From R_1=1.78.Nosberger and Joggi (2001) stated that stem density is initially determined by seed rate and physiological age of seed tubers. As to the evidence, nitrogen modifies the impacts of these structures fundamentally, even though it acts on the degree of branching over the soil surface.

Number of tubers per bush

There is a statistically significant difference between fertilizer sources at p=5% as to their acting on the number of tubers per bush (see Table 1), whereas this is not true between treatments of times and amounts of N application. Maximum number of tubers was obtained from ammonium sulfate fertilizer with 6.86 tubers per bush and the minimum came from urea fertilizer source equaling 6.77. The highest number obtained from T2 was 7.05 while the lowest rate came from T1 equaling 6.54 (Tables 2 and 3). The existence of appropriate leaf areas at the sensitive stage of tuber enlargement with leaf area sustainability maintenance, a high growth speed, achieving an acceptable aerial organ biomass at the tuber enlargement stage and finally having a higher mean tuber weight per square meter contribute to the above results. It is likely that all such positive effects of T2 occur due to the right timing for N application, supporting the plant community with catching the sunlight, CO_2, nutrients and finally accumulation of carbohydrate. The highest number for stem per bush was gained from R_2= 7.08 in value and the lowest from R_1= 6.46 (Tables 2 and 3). The highest number for stem per bush was gained from R_2= 7.08 in value and the lowest from R_1= 6.46 (tables 2 and 3). In this study, we did not observe any significance regarding changes in the number of tubers at various N levels. In Gunasena and Harris (2017)'s research, the highest number for stem per bush was gained from R2= 7.08 in value and the lowest from R_1= 6.46 (Tables 2 and 3). In this study, we did not observe any significance regarding changes in the number of tubers at various N levels. In Gunasena and Harris (2017)'s research, an increase in N before stimulating the tubers raised their number up to 60% as compared to the evidence treatment; however, this rise fell strikingly to a downward trend during the harvest. If the fertilization was delayed until after its initiation time, there would be no effects on the number of stems. An excess application of N will stimulate leaf and brunch growth status and postpones tuber formation (Rezayee and Soltani, 2010).

Tuber weight

As table 1 demonstrates, there is no statistically significant difference between fertilizer sources treatments in their affecting the tubers weight. Yet this significance is observed between treatments of time and N application amounts at p=1% . Maximum tuber weight was obtained from urea fertilizer with 117.47 g and the minimum rate from ammonium sulfate with 97.98g (Tables 2, 3). Probably, the reason for such a rise lies in the urea fertilizer being available to the plant in the growth season and in the unavailability of ammonium sulfate due to nitrification (ammonium converted into nitrate) and nitrate leaching. Maximum weight from T_1 was 124.62 g and the minimum from T3 equaled 92.58 g. The results indicate that T_1 and T_2-the consumption times-were the best to obtain large tubers. Consequently, with N provision (at the two times) early in the growth season the potato plant is provided with less root expansion so as to have less starting points of tuber formation and stolen but in contrast larger tubers at the end of the season. The highest rate of tuber weight from R_3 was 120.66 g and the lowest from R1 equaled 96.55 (Table 2). According to Echeverria et al. (2000), increase in the nitrogen content raised the dry weight of the entire plant, leaf area index and the absorbed light by plant but declined the harvest index slightly. A rise in tuber weight simultaneous with the first level of increase in nitrogen may follow from the rhythm of weight increase and the probable participation of longer periods of tuber weight increase. It appears that leaf area sustainability intensifies as N rises in use and this in turn increases the tuber weight. An increase in N raised the mean tuber weight, reported in the other studies too (Molerhagen, 2000; Osaki at al, 2012; Prosba, 2002; Reust, 2009). Nevertheless, in the research by Hasandokht and et al., the application of nitrogen did not affect the mean tuber weight.

Table 2: Mean comparisons of the effect of N consumption rates and times on some traits of potato.

Tuber weight (g)	Number of tuber	Number of stem	Yield (ton.ha^{-1})	traits / factor
Nitrogen Fertilizer Resource				
17.47^{a}	6.77^{b}	1.90^{b}	27.38^{a}	Urea
97.98^{a}	27.38^{a}	1.94^{a}	19.33^{b}	Ammonium Sulfate
Time of N Application				
124.62^{a}	6.54^{a}	1.58^{a}	19.83^{b}	During Cultivation
105.98^{b}	7.05^{a}	2.01^{a}	30.08^{b}	1/2 at cultivation+1/2 at the beginning of flowering
92.58^{c}	6.56^{a}	1.9^{a}	20.18^{b}	1/3 at cultivation+1/3 at soil hilling+ the beginning of the flowering

N fertilizer Amount(kg/ha)				
96.55^{c}	6.46^{a}	1.78^{a}	19.5^{b}	150
105.96^{b}	7.08^{a}	1.94^{a}	23.88^{a}	200
120.66^{a}	6.91^{a}	2.03^{a}	26.72^{a}	250

Means within columns with like letters are not significantly different at the 5% level based on the Duncan test.

Table 3: Mean comparisons of the interactive effects of N fertilizer resources,consumption rates and times on some traits of potato

N application time	N fertilizer Rate	Yield (ton.ha-1)	Number of stem	Number of tuber	Tuber weight (g)
		Urea			
At cultivation	150	20^{ab}	1.93^{a}	7.33^{ab}	109.26^{c}
	200	18.66^{ab}	1.73^{a}	6.53^{ab}	109.19^{c}
	250		1.66^{a}	7.33^{ab}	935.22^{a}
$\frac{1}{2}$at cultivation+ $\frac{1}{2}$	150	30ab	2a	5.73abc	101.52bc
at the beginning of	200	37.5a	2.06a	7a	108.56abc
flowering	250	40a	2.2a	867.7a	110.083abc
$\frac{1}{3}$at cultivation+ $\frac{1}{3}$	150	20^{a}	1.667^{a}	5.8^{a}	100.099^{bod}
at soil hiling+the	200	28^{ab}	2.67^{a}	7.867^{a}	105.537^{bod}
beginning of the	250	25^{ab}	1.8^{a}	5.533^{a}	91.98^{od}
flowering					
Ammonium sulfate					
At cultivation	150	15^{a}	1.8^{a}	5.8^{abc}	112.06^{ab}
	200	18^{a}	1.73^{ba}	5.73^{abc}	95.11^{bc}
	250	20^{a}	2.26^{a}	6.53^{abc}	101.16^{bc}
$\frac{1}{2}$at cultivation+ $\frac{1}{2}$	150	18^{a}	1.53^{a}	8.13^{abc}	97.61^{b}
At the beginning of	200	25^{ab}	2.33a	6.53^{c}	118.68^{a}
Flowering	250	30^{ab}	1.93a	$7.06b^{c}$	99.36^{b}
$\frac{1}{3}$at cultivation+ $\frac{1}{3}$	150	14^{a}	1.8^{a}	6^{c}	58.78^{b}
At soil hilling+the	200	16^{a}	1.73^{a}	8.86^{abc}	98.62^{ab}
Beginning of the	250	18^{a}	2.33^{a}	7.13^{bc}	100.67^{a}
flowering					

Cultivations of like letters are not significantly different at the 5./. level based on the Duncan test

Conclusion

Here we investigated the impacts of nitrogen fertilizer resources, rate and timing on yield and yield components of potato. Our results showed that a maximum yield of potato arose from the application of 250 kg/ha urea fertilizer half of which was consumed at planting and the other half simultaneous with the beginning stage of flowering.

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