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Assessing the Impacts of Some Sustainable Agricultural Practices for Yield Improvement on Potato (*Solanum tuberosum* L.)

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Abstract: Three N rates; 150, 200 and 250 kg fed^{-1}, two in-row spacing's of 20 and 30 cm and three planting dates starting from January 15 with two weeks interval were investigated in two field experiments under El-Fayoum conditions which is not potato production district in Egypt. Results cleared that, N application at 150 kg fed^{-1} was satisfactory on total tubers yield and most of its components. In-row spacing of 20 cm, significantly, surpassed 30 cm in total tubers yield fed^{-1} and number of tubers plant^{-1}. Seed planting date on Jan. 30, significantly, produced higher total tubers yield fed^{-1} and its components compared to Jan. 15 and Feb. 14. The combined treatment of seed planting date on Jan. 30 plus in-row spacing of 20 cm coupled with 200 and/or 250 kg N fed^{-1} gained the best significant mean value of total tubers yield fed^{-1}.

Key words: *Solanum tuberosum* · Sustainable agriculture · Nitrogen · In-row spacing · Planting dates · Growth and yield

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the fourth main food crop in the world after maize, rice and wheat [1]. Potatoes are important to both industrialized and developing countries as a source of income and are a staple food for the world population. The association between above-ground and under-ground organs of potato plant linked with total tubers yield [2]. Plant growth involves various environmental and agronomical factors[3, 4]. Among these factors, Nitrogen fertilization, in-row spacing and planting time play special roles in growth of canopy, tuber productivity and quality of potatoes. Previous studies have shown that N fertilizer can increase the growth criteria [5, 6]. Appropriate use of N can lead to the achievement of optimum canopy development and increase tuber yield but, excessive use of N can lead to delay of maturity, competition between sink and source with tuber yield inferior, N losses through leaching, pollution of ecosystems and has negative effects on human public health [7, 8].

In-row spacing between potato plants is contributing factor for tubers production. Suitable in-row spacing enhances earlier farm full coverage and consequently reduces evaporation and soil temperature and increase water use efficiency [9]. Preceding reports showed that, wide in-row spacing's between potato plants increased tubers hill^{-1}, average tuber weight and individual plant productivity but, the tubers yield ha^{-1} did not follow the same trend [10-12].

Potato is characterized by specific temperature requirements and develops best at about 20 C°. Growth of potato plants have difficulty with hot weather conditions because respiration increased, dry matter accumulation decreased and net assimilation rate is few. Therefore, optimum seed planting time is so vital and reflected on plant growth, tubers production and quality. Early planting time of potato, significantly, produced greater total and marketable tuber yields than late planting time [13]. Average potato tuber weight was heavier with early than late planting time [14, 15].

Accordingly, the current study was introduced as an attempt to recognize appropriate N applied dose, correct in-row spacing between plants and right time of planting date to gain optimum potato yield under El-Fayoum Governorate conditions which is not a district of potato production in Egypt.

MATERIALS AND METHODS

Experimental Procedures: Two similar field experiments, each in summer season of 2014 and 2015, were imposed at

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Table 1: Some initial chemical and physical characteristics of the experimental soil in 2014 and 2015 seasons

	Value	
Physical characteristics (%)	2014	2015
Silt	8.00	9.11
Clay	53.01	52.90
Fine sand	29.34	30.36
Coarse sand	9.65	7.36
Soil texture	Clayey	Clayey
Chemical characteristics		
pH [at a soil: water (w/v) ratio of 1:2.5]	8.01	7.88
ECe (dS/m; soil - paste extract)	3.22	2.95
Organic matter (%)	0.56	0.75
N (%)	0.006	0.010
$CaCO_3$ (%)	10.12	11.04

Table 2: Maximum, minimum and average air temperature month^{-1} during the two growing seasons of 2014 and 2015

	Temperature (C°)					
	2014			2015		
Month	Maximum	Minimum	Average	Maximum	Minimum	Average
January	23.65	9.69	16.67	22.45	10.30	16.37
February	25.89	11.19	18.54	23.60	10.50	17.05
March	*---------	----------	----------	-------	-------	-------
April	30.39	15.39	22.89	32.80	15.70	24.25
May	37.37	21.43	29.40	36.97	21.65	29.31
June	39.48	23.43	31.45	34.86	21.70	28.28

* Unrecorded data.

a private farm located at Tatoon, Etsa, El-Fayoum Governorate, Egypt. The goal of the experiments is to examine the main and interaction effects of N fertilization rates; 150, 200 and 250 kg fed^{-1}, in-row spacing between plants; 20 and 30 cm and seed planting dates; Jan. 15, Jan. 30 and Feb. 14 on potato crop. To identify some physio-chemical features of the experimental site, soil samples of 30 cm depth were collected, prior the initiation of each experiment and analyzed at Soil Laboratory Test, Faculty of Agriculture, Fayoum University according to the standard published procedures [16]. Results of the analyses are presented in Table 1. Maximum, minimum and average air temperature month^{-1} during the two growing seasons provided by Meteorological Station at Etsa, Fayoum Governorate, Egypt are listed in Table 2.

Imported potato tuber seeds cv. Spunta class E was used. Tuber seeds cutted, cured and well sprouted and each seed piece weigh ranged between 55 – 60 g. Potato seed pieces were planted on Jan. 15, Jan. 30 and Feb. 14 at in-row spacing's of 20 and 30 cm. Nitrogen rates were side banded at two equal applications; after complete earthing and 21 days thereafter. The respective form of 1st and 2nd N applications was ammonium nitrate (33% N) and ammonium sulphate (20.5% N), respectively. Identical doses of P_2O_5 and K_2O at 45 and 96 kg fed^{-1}, respectively were applied to all experimental units. All other agro-management practices like irrigation and pests control were achieved. After 110 days of seed sowing, irrigation was stopped and 7 days later canopy was manually removed. Harvest was performed after 120 days of seed sowing dates.

The experimental layout was a split-split-plot system based on Randomized Complete Design with four replications. Nitrogen rates, In-row spacing's and planting dates were randomly distributed within the main, sub - and sub-sub-plots, orderly. Each experimental unit included four rows of 4 m long and 0.7 m wide. Each two adjacent experimental unites were separated by two guard rows to protect against border effects.

Data Recorded: After 90 days of seed sowing, four plants from the two outer rows in each experimental unit were randomly chosen, cut off at the ground level and the following measurements were recorded; plant height (cm) starting from the ground level to the apical meristem of the main stem, canopy dry weight(g) plant^{-1} by drying in a forced-air oven at 70°C till the weight became constant and total leaves area plant^{-1} (dm^{-2}) using leaf area - leaf

weight relationship as illustrated by [17]. After 120 days of seed sowing, all plants of the two inner rows in each experimental unit were harvested. Tubers number plant^{-1}, average tuber weight (g), tubers yield plant^{-1} (kg) and total tubers yield fed^{-1}(tone) were calculated. Comparisons among mean treatments were performed using the Revised Least Significant Difference procedure at P= 0.05 level [18].

RESULTS AND DISCUSSION

Plant Height: Response of plant height to N rate, in-row spacing and seed planting date was listed in Table 3. Response of plant height to N applied rates; 150, 200 and 250 kg fed^{-1} was significant, in 2015 season and the trend was approximately the same in both seasons. In 2015 season, N rate at 150 kg fed^{-1}, significantly, recorded taller plant height than 200 and 250 kg fed^{-1}. Similar finding was reported by [19] who exhibited that, increasing N fertilization rate of potato plants over 200 kg N fed^{-1} reflected a negative effect on plant height. The influence of in-row spacing's between plants; 20 and 30 cm did not reflect any appreciable effect on plant height, in both seasons. Comparisons among the mean values of seed planting dates indicated that, progressive and significant increments in plant height due to delaying seed planting date from Jan. 15 to Jan. 30 and furtherly to Feb. 14. The enhancing influence of seed planting date on Feb. 14 than Jan. 15 and 30 on plant height may be realized on the basis that, the temperature during seed planting date of Feb. 14 is higher than those of earlier planting dates (Table 2). High temperature is known to accelerate growth rate and thus, late seed planting date possibly produced more vigor growth including taller plant stature. Previous result reached to the same conclusion [20].

The effect of 1st order interaction between any two studied factors and 2nd order interaction among the three studied factors were not significant, in both seasons except the 1st order interaction between N applied levels and seed planting dates, in 2015 season. At any planting date, increasing N applied level from 150 to 200 and furtherly to 250 kg fed^{-1} decreased plant height. At any N level, late seed planting date from Jan. 15 to 30 and furtherly to Feb. 14 increased plant height. Therefore, Late seed planting date on Feb. 14 combined with the addition of 150 kg N fed^{-1}, significantly, attained the highest mean value of plant height whereas, early seed planting date on Jan. 15 associated with the addition of 150 kg N fed^{-1}, significantly, recorded the lowest one.

Canopy Dry Weight Plant^{-1}: The main and interaction effects of N applied rate, in-row spacing and seed planting date on canopy dry weight plant^{-1} are illustrated in Table 4. Response of canopy dry weight to N application rates was, significantly, varied, in both seasons. In 2015 season, increasing N applied rate over 150, truly, decreased canopy dry weight plant^{-1}. The same trend was obvious in 2014 season but, the differences were too small to be significant. Previous investigators showed that, the dry matter accumulation and growth of potato plants increased to a particular N level, beyond it the response became negative or at par[6, 21, 22]. Potato plants received 67.5 and 135 kg N fed^{-1} did not differ in canopy dry weight plant^{-1} [23]. No significant differences in

Table 3: Main and interactive effects of nitrogen rates, in-row spacings and planting dates on plant height (cm) of potato, in the summer seasons of 2014 and 2015

		2014				2015			
		N rate(kg fed^{-1})				N rate(kg fed^{-1})			
In-row Spacing (cm)	Planting date	150	200	250	Mean	150	200	250	Mean
20	Jan. 15th	30.50^{a*}	31.63^{a}	32.42^{a}	31.52^{a}	30.87^{a}	30.97^{a}	29.61^{a}	30.48^{a}
	Jan. 30th	49.94^{a}	49.63^{a}	43.17^{a}	47.58^{a}	35.02^{a}	33.15^{a}	36.41^{a}	34.86^{a}
	Feb. 14th	55.42^{a}	55.25^{a}	50.50^{a}	53.72^{a}	48.36^{a}	40.53^{a}	43.41^{a}	44.10^{a}
30	Jan. 15th	33.83^{a}	34.04^{a}	28.79^{a}	32.22^{a}	31.96^{a}	30.64^{a}	27.63^{a}	30.07^{a}
	Jan. 30th	56.43^{a}	47.35^{a}	48.96^{a}	50.91^{a}	35.42^{a}	34.35^{a}	36.07^{a}	35.28^{a}
	Feb. 14th	48.00^{a}	54.00^{a}	53.67^{a}	51.89^{a}	45.88^{a}	34.03^{a}	39.37^{a}	39.76^{a}
20		45.29^{a}	45.50^{a}	42.03^{a}	44.27^{A}	38.08^{a}	34.88^{a}	36.47^{a}	36.48^{A}
30		49.09^{a}	45.13^{a}	43.81^{a}	45.01^{A}	37.75^{a}	33.01^{a}	34.35^{a}	35.04^{A}
	Jan. 15th	32.17^{a}	32.83^{a}	30.61^{a}	31.87^{C}	31.41^{de}	30.80^{de}	28.62^{e}	30.28^{C}
	Jan. 30th	53.19^{a}	48.49^{a}	46.06^{a}	49.25^{B}	35.22^{cd}	33.75^{cd}	36.24^{c}	35.07^{B}
	Feb. 14th	51.71^{a}	54.63^{a}	52.08^{a}	52.81^{A}	47.12^{a}	37.28^{bc}	41.39^{b}	41.93^{A}
	Mean	45.69^{A}	45.32^{A}	42.92^{A}		37.92^{A}	33.94^{B}	35.41^{B}	

*Values marked with the same letter(s) within the main and interaction effects are statically similar using Revised LSD. Test at probability = 0.05. Uppercase letter(s) indicate differences between main effects whilst, lowercase letter(s) refer to differences between interaction.

Table 4: Main and interactive effects of nitrogen rates, in-row spacing and planting dates on canopy dry weight plant^{-1}(g) of potato, in the summer seasons of 2014 and 2015

		2014				2015			
		N rate(kg fed^{-1})				N rate(kg fed^{-1})			
In-row Spacing (cm)	Planting date	150	200	250	Mean	150	200	250	Mean
20	Jan. 15th	19.96^{g*}	22.75^{fg}	22.70^{fg}	21.80^{a}	25.67^{a}	31.31^{a}	30.63^{a}	29.20^{a}
	Jan. 30th	37.22^{cd}	49.35^{ab}	34.95^{c-d}	40.50^{a}	38.09^{a}	27.67^{a}	29.83^{a}	31.86^{a}
	Feb. 14th	39.53^{b-d}	35.04^{c-e}	38.76^{b-d}	37.78^{a}	40.14^{a}	37.45^{a}	28.40^{a}	35.33^{a}
30	Jan. 15th	24.08^{e-g}	25.55^{e-g}	20.39^{fg}	23.34^{a}	26.61^{a}	25.97^{a}	24.66^{a}	26.75^{a}
	Jan. 30th	51.78^{a}	31.24^{ef}	42.26^{a-c}	41.76^{a}	32.86^{a}	28.55^{a}	27.49^{a}	29.63^{a}
	Feb. 14th	35.07^{c-e}	37.38^{cd}	36.99^{cd}	36.48^{a}	42.00^{a}	33.18^{a}	24.69^{a}	33.29^{a}
20		32.23^{a}	35.71^{a}	32.14^{a}	33.36^{A}	34.63^{a}	32.14^{a}	29.62^{a}	32.13^{A}
30		36.98^{a}	31.39^{a}	33.21^{a}	33.86^{A}	34.82^{a}	29.23^{a}	25.61^{a}	29.89^{A}
	Jan. 15th	22.02^{b}	24.15^{b}	21.55^{b}	22.57^{B}	27.64^{b}	28.64^{b}	27.65^{b}	27.97^{B}
	Jan. 30th	44.50^{a}	40.29^{a}	38.60^{a}	41.13^{A}	41.07^{a}	35.31^{a}	26.66^{b}	34.35^{A}
	Feb. 14th	37.30^{a}	36.21^{a}	37.88^{a}	37.13^{A}	35.47^{a}	28.11^{b}	26.55^{b}	30.04^{AB}
	Mean	34.61^{A}	33.55^{A}	32.67^{A}		34.73^{A}	30.69^{B}	26.95^{B}	

*Values marked with the same letter(s) within the main and interaction effects are statically similar using Revised LSD. Test at probability = 0.05. Uppercase letter(s) indicate differences between main effects whilst, lowercase letter(s) refer to differences between interaction.

canopy dry weight plant^{-1} between in-row distance; 20 and 30 cm, in both seasons. Seed planting date, truly, affected canopy dry weight plant^{-1}, in both seasons. Seed planting date on Jan. 30 resulted in the heaviest canopy dry weight plant^{-1}. The promoting effect of seed planting date on Jan. 30 than Jan. 15 and Feb. 14 on canopy dry weight plant^{-1} can be discussed on the ground that, when potato seeds were sown early or late, the resulting plants entered the flowering–maturation phase early due to unfavorable temperature and/or light period and hence the growth of aerial parts was restricted. The obtained results are in harmony with [24].

The 1st order interaction between any two studied factors did not had any, significant, influence on canopy dry weight plant^{-1} with one exception between N rates and seed planting dates, in both seasons. Comparisons among the nine mean values of this significant interaction indicated that, the treatment of seed planting date on Jan. 30 and 150 kg N fed^{-1} together, significantly, recorded the heaviest mean value of canopy dry weight plant^{-1}. The 2nd order interaction among the three studied factors had significant effect on canopy dry weight plant^{-1}, in 2014 season only. Comparisons among the eighteen mean values of this significant interaction displayed that, planting potato seed on Jan. 30 at in-row spaced 30 cm and applied 150 kg N fed^{-1}, significantly, resulted in the highest mean value of canopy dry weight plant^{-1}.

Total Leaves Area Plant^{-1}: Results of the main and different order interactions effect of the three studied factors on total leaves area plant^{-1}, in 2014 and 2015 seasons, are listed in Table 5. The effect of N rates on total leaves area plant^{-1} was, statistically, varied between the two in quested seasons. In 2015 season, increasing N applied rate over 150 kg fed^{-1}, significantly, depressed total leaves area plant^{-1}. The same trend was obvious in 2014 season nevertheless, the differences did not reach the significant level. This conclusion can be explained on the ground that, as an average of the two seasons, N application at 150 kg fed^{-1} relative to 200 and 250 kg N fed^{-1} increased plant height by 6.27 and 6.77% (Table 3) and canopy dry weight plant^{-1} by 8.16 and 17.40% (Table 4), orderly. Accordingly, N application at 150 kg fed^{-1} increased total leaves area plant^{-1} over 200 and 250 kg fed^{-1} by 8.00 and 18.14%, respectively (Table 5). Similar conclusion was reported by[22].Response of total leaves area plant^{-1} to in-row spacing's between plants; 20 and 30 cm was not intrinsic, in both years.Seed planting dates, significantly, affected total leaves area plant^{-1}, in the two experimental seasons. Seed planting date on Jan. 30 was remarkable and, significantly, produced the largest total leaves area plant^{-1}. The favorable influence of seed planting date on Jan. 30 than Jan. 15 and Feb. 14 in total leaves area plant^{-1} may be due to the increment in number of lateral branches, number of leaves plant^{-1} and somewhat leaf area leaf^{-1} (Data not shown). Our results are in accordance with the findings of [25] who pointed out that, the latest planting time decreased leaf area index in all tested potato varieties and the earliest one had the smallest leaf areas plant^{-1}. Plants resulted from late planting time contained lower number of leaves plant^{-1}[20].

Table 5: Main and interactive effects of nitrogen rates, in-row spacing and planting dates on total leaves area plant^{-1} (dm^{-2}) of potato, in the summer seasons of 2014 and 2015

		2014				2015			
		N rate(kg fed^{-1})				N rate(kg fed^{-1})			
1n-row Spacing (cm)	Planting date	150	200	250	Mean	150	200	250	Mean
20	Jan. 15th	406.0^{a*}	461.9^{a}	464.3^{a}	444.1^{a}	487.1^{a}	634.9^{a}	614.1^{a}	578.7^{a}
	Jan. 30th	837.4^{a}	991.8^{a}	646.4^{a}	825.2^{a}	790.7^{a}	515.4^{a}	523.6^{a}	609.9^{a}
	Feb. 14th	929.8^{a}	886.4^{a}	900.0^{a}	905.4^{a}	512.0^{a}	479.8^{a}	352.0^{a}	447.9^{a}
30	Jan. 15th	535.1^{a}	884.6^{a}	397.4^{a}	472.4^{a}	557.6^{a}	496.6^{a}	459.9^{a}	504.7^{a}
	Jan. 30th	797.8^{a}	895.9^{a}	888.7^{a}	860.8^{a}	570.9^{a}	510.2^{a}	474.8^{a}	518.6^{a}
	Feb. 14th	1017.5^{a}	629.1^{a}	858.3^{a}	843.9^{a}	531.2^{a}	442.9^{a}	283.0^{a}	419.0^{a}
20		724.4^{a}	780.0^{a}	670.2^{a}	724.9^{A}	553.2^{a}	483.2^{a}	405.9^{a}	480.8^{A}
30		783.5^{a}	669.9^{a}	714.8^{a}	722.7^{A}	596.6^{a}	543.4^{a}	496.6^{a}	545.5^{A}
	Jan. 15th	470.6^{a}	473.3^{a}	430.9^{a}	458.2^{B}	522.4^{b}	565.8^{ab}	537.0^{b}	541.7^{A}
	Jan. 30th	883.8^{a}	891.2^{a}	894.3^{a}	883.1^{A}	680.8^{a}	512.8^{b}	499.2^{b}	564.3^{A}
	Feb. 14th	927.5^{a}	810.4^{a}	752.3^{a}	830.1^{B}	521.6^{a}	461.4^{b}	317.5^{c}	433.5^{B}
	Mean	753.9^{A}	724.9^{A}	692.5^{A}		574.9^{A}	513.3^{B}	451.2^{B}	

*Values marked with the same letter(s) within the main and interaction effects are statically similar using Revised LSD. Test at probability = 0.05. Uppercase letter(s) indicate differences between main effects whilst, lowercase letter(s) refer to differences between interaction.

Table 6: Main and interactive effects of nitrogen rates, in-row spacing and planting dates on ontubers number plant^{-1}of potato, in the summer seasons of 2014 and 2015

		2014				2015			
		N rate(kg fed^{-1})				N rate(kg fed^{-1})			
In-row Spacing (cm)	Planting Date	150	200	250	Mean	150	200	250	Mean
20	Jan. 15th	4.33^{c*}	4.76^{bc}	4.80^{bc}	4.63^{b}	5.15^{a}	5.12^{a}	5.08^{a}	5.12^{a}
	Jan. 30th	6.65^{bc}	4.81^{bc}	6.60^{bc}	6.02^{b}	7.61^{a}	8.39^{a}	10.14^{a}	8.71^{a}
	Feb. 14th	5.18^{bc}	4.86^{bc}	4.77^{bc}	4.93^{b}	6.54^{a}	5.87^{a}	5.70^{a}	6.04^{a}
30	Jan. 15th	4.38^{c}	4.49^{c}	5.81^{bc}	4.89^{b}	5.88^{a}	5.07^{a}	4.97^{a}	5.31^{a}
	Jan. 30th	7.67^{b}	12.98^{a}	7.01^{bc}	9.22^{a}	10.18^{a}	9.30^{a}	7.73^{a}	9.07^{a}
	Feb. 14th	5.09^{bc}	4.05^{c}	6.04^{bc}	5.06^{b}	7.99^{a}	6.41^{a}	6.07^{a}	6.82^{a}
20		5.71^{a}	7.17^{a}	6.29^{a}	6.39^{A}	8.02^{a}	6.93^{a}	6.26^{a}	7.07^{A}
30		5.39^{a}	4.81^{a}	5.39^{a}	5.19^{B}	6.43^{a}	6.46^{a}	6.97^{a}	6.62^{B}
	Jan. 15th	4.35^{a}	4.62^{a}	5.30^{a}	4.76^{B}	5.51^{a}	5.10^{a}	5.03^{a}	5.21^{C}
	Jan. 30th	7.16^{a}	8.90^{a}	6.81^{a}	7.62^{A}	8.89^{a}	5.85^{a}	8.93^{a}	8.89^{A}
	Feb. 14th	5.13^{a}	4.45^{a}	5.40^{a}	5.00^{B}	7.27^{a}	6.14^{a}	5.88^{a}	6.43^{B}
	Mean	5.55^{A}	5.99^{A}	5.84^{A}		7.22^{A}	6.69^{B}	6.61^{B}	

*Values marked with the same letter(s) within the main and interaction effects are statically similar using Revised LSD. Test at probability = 0.05. Uppercase letter(s) indicate differences between main effects whilst, lowercase letter(s) refer to differences between interaction.

The influences of 1st and 2nd order interactions between and among the three studied factors on total leaves area plant^{-1} were not true, in both seasons with the exception of 1st order interaction between N rates and seed planting dates, in 2015 season. Comparisons among the nine mean values of this significant interaction displayed that, seed planting date on Jan. 30 coupled with N rate of 150 kg fed^{-1}, significantly, surpassed all other interactions.

Tubers Yield and its Components

Tubers Number Plant^{-1}: The main effects of N rate, in-row spacing between plants, seed planting date and their different order interactions on tubers number plant^{-1} are shown in Table 6. In 2015 season, application of N at 150 kg fed^{-1} was responsible for the statistically increment in number of tubers plant^{-1} over 200 and 250 kg N fed^{-1} nevertheless, the difference between the two later N rates was not true. In 2014 season, application of N rates at 150, 200 and 250 kg fed^{-1} did not reflect any appreciable influence on number of tubers plant^{-1}. Significant more numbers of tubers plant^{-1} was produced at in-row spacing of 20 than 30 cm between plants, in both seasons. Significant higher number of tubers plant^{-1} was attained when seed potatoes were planted on Jan. 30 than Jan. 15 and Feb. 14, in the two in quested seasons.

Table 7: Main and interactive effects of nitrogen rates, in-row spacing and planting dates on average tuber weight (g) of potato, in the summer seasons of 2014 and 2015

		2014				2015			
		N rate(kg fed^{-1})				N rate(kg fed^{-1})			
In-row Spacing (cm)	Planting date	150	200	250	Mean	150	200	250	Mean
20	Jan. 15th	120.0^{a*}	120.0^{a}	110.0^{a}	116.7^{c}	120.0^{a}	120.0^{a}	120.0^{a}	120.0^{c}
	Jan. 30th	190.0^{a}	200.0^{a}	200.0^{a}	193.3^{a}	140.0^{a}	170.0^{a}	170.0^{a}	160.0^{a}
	Feb. 14th	190.0^{a}	160.0^{a}	130.0^{a}	160.0^{b}	150.0^{a}	150.0^{a}	140.0^{a}	146.7^{b}
30	Jan. 15th	130.0^{a}	120.0^{a}	120.0^{a}	123.3^{c}	140.0^{a}	160.0^{a}	130.0^{a}	143.3^{b}
	Jan. 30th	170.0^{a}	180.0^{a}	170.0^{a}	173.3^{b}	140.0^{a}	160.0^{a}	160.0^{a}	153.3^{ab}
	Feb. 14th	150.0^{a}	140.0^{a}	110.0^{a}	133.3^{a}	110.0^{a}	100.0^{a}	100.0^{a}	103.3^{d}
20		150.0^{a}	140.0^{a}	130.0^{a}	140.0^{B}	120.0^{a}	140.0^{a}	130.0^{a}	130.0^{B}
30		170.0^{a}	160.0^{a}	140.0^{a}	156.7^{A}	160.0^{a}	150.0^{a}	140.0^{a}	150.0^{A}
	Jan. 15th	130.0^{a}	120.0^{a}	110.0^{a}	120.0^{C}	120.0^{a}	110.0^{a}	110.0^{a}	113.3^{C}
	Jan. 30th	180.0^{a}	190.0^{a}	180.0^{a}	183.3^{A}	180.0^{a}	160.0^{a}	150.0^{a}	163.3^{A}
	Feb. 14th	170.0^{a}	150.0^{a}	120.0^{a}	146.7^{B}	146.7^{a}	140.0^{a}	160.0^{a}	150.0^{B}
	Mean	159.1^{A}	152.7^{A}	137.3^{A}		138.2^{A}	143.6^{A}	136.4^{A}	

*Values marked with the same letter(s) within the main and interaction effects are statically similar using Revised LSD. Test at probability = 0.05. Uppercase letter(s) indicate differences between main effects whilst, lowercase letter(s) refer to differences between interaction.

The sole 1st order interaction between in-row spacing by seed planting date was significant, in 2014 season. Comparisons among the six mean values of this significant interaction showed that, planting potato seeds on Jan. 30 at in-row spacing of 30 cm achieved the highest number of tubers plant^{-1}. The interactive effect among the three studied factors on number of tubers plant^{-1} was true, in 2014 season. Comparisons among the 18th combined treatments showed that, seed planting date on Jan. 30 at in-row spacing of 30 cm coupled with 200 kg N fed^{-1} appeared to produce the best number of tubers plant^{-1} (12.98 tubers plant^{-1}).

Average Tuber Weight: Average tuber weight as affected by the three studied factors and their different interactions is illustrated in Table 7. Response of average tuber weight to different N doses was not significant, in both seasons. Average tuber weight was, significantly, heavier at in-row spacing of 30 than 20 cm, in both years. Average tuber weight, significantly and progressively, declined as seed planting dates were on Jan. 30, Feb. 14 and Jan. 15 in 2014 and 2015 seasons, respectively.

The only significant interaction between seed planting date and in-row distance between plants was discovered, in both seasons. The heaviest average tuber weight was achieved when seed planting date on Jan. 30 together with in-row spacing of 20 cm, in both years.

Tubers Yield Plant^{-1}: The general influence of different N rates; 150, 200 and 250 kg fed^{-1} and in-row spacing's between plants; 20 and 30 cm on tubers yield plant^{-1} appeared to be not significant, in both seasons (Table 8). However, seed planting dates on Jan. 30, Feb. 14 and Jan. 15, progressively and significantly, decreased total tubers yield plant^{-1}, orderly indicating the best seed planting date is Jan. 30.

The impact of 1st order interactions between seed planting date, in one side, by in-row spacing and N level, in another side, on tubers yield plant^{-1} was significant, in both seasons. The results, obviously, cleared that, the interactive treatments of seed planting date on Jan. 30 by in-row spacing's at 20 and /or 30 cm or by N rates of 150 and/or 200 N kg fed^{-1} were responsible for recording maximum tubers yield plant^{-1}. The 2nd order interaction among seed planting date on Jan. 30 at in-row spacing's 20 and/ or 30 cm together with N rates 200 and/or 250 kg fed^{-1} were the integrated treatment that recorded the best tubers yield plant^{-1}.

Total Tubers Yield Fed^{-1}: The main influence of N rates on total tubers yield fed^{-1} was not significant, in both seasons however, the main influences of in-row spacing and seed planting date were intrinsic, in both seasons (Table 9). Narrow in-row spacing between plants (20 cm), significantly, attained heavier total tubers yield fed^{-1} than the wider one (30 cm), in both years. Total tubers yield fed^{-1}, significantly, ranked the 1st when seed planting date was on Jan. 30 followed by Feb. 14 and Jan. 15, orderly, in both seasons.

The effect of 1st order interaction between in-row spacing's and seed planting dates on total tubers yield fed^{-1} was significant, in both seasons. Seed planting date on Jan. 30 at in-row spacing of 20 cm was distinguish and recorded the heaviest total tubers yield fed^{-1}, in 2014

Table 8: Main and interactive effects of nitrogen rates, in-row spacing and planting dates on ontubers yield plant^{-1} (kg) of potato in the summer seasons of 2014 and 2015

		2014				2015			
		N rate(kg fed^{-1})				N rate(kg fed^{-1})			
In-row spacing (cm)	Planting date	150	200	250	Mean	150	200	250	Mean
20	Jan. 15th	0.520^{g*}	0.571^{eg}	0.528^{fg}	0.540^{c}	0.618^{e}	0.614^{e}	0.610^{e}	0.614^{c}
	Jan. 30th	1.264^{b}	0.962^{cd}	1.254^{b}	1.250^{b}	1.065^{c}	1.426^{b}	1.724^{a}	1.405^{a}
	Feb. 14th	0.984^{bd}	0.778^{de}	0.620^{eg}	0.794^{c}	0.981^{cd}	0.881^{cd}	0.798^{de}	0.887^{b}
30	Jan. 15th	0.569^{eg}	0.539^{fg}	0.697^{eg}	0.602^{c}	0.823^{de}	0.811^{de}	0.646^{e}	0.760^{bc}
	Jan. 30th	1.304^{b}	2.336^{a}	1.192^{bc}	1.611^{a}	1.425^{b}	1.488^{b}	0.773^{de}	1.229^{a}
	Feb. 14th	0.764^{df}	0.567^{eg}	0.664^{eg}	0.665^{c}	0.879^{cd}	0.641^{e}	0.789^{de}	0.770^{bc}
20		0.857^{a}	1.000^{a}	0.818^{a}	0.892^{A}	0.962^{a}	0.970^{a}	0.876^{a}	0.936^{A}
30		0.916^{a}	0.770^{a}	0.775^{a}	0.814^{A}	1.029^{a}	0.969^{a}	0.767^{a}	0.921^{A}
	Jan. 15th	0.566^{a}	0.544^{d}	0.583^{d}	0.568^{C}	0.661^{ef}	0.561^{f}	0.755^{df}	0.659^{C}
	Jan. 30th	1.289^{b}	1.691^{a}	1.226^{ab}	1.360^{A}	1.600^{a}	1.416^{ab}	1.340^{b}	1.452^{A}
	Feb. 14th	0.872^{cd}	0.668^{d}	0.648^{d}	0.690^{B}	1.018^{c}	0.982^{cd}	0.882^{ce}	0.961^{B}
	Mean	0.900^{A}	0.949^{A}	0.817^{A}		1.006^{A}	0.887^{A}	0.905^{A}	

*Values marked with the same letter(s) within the main and interaction effects are statically similar using Revised LSD. Test at probability = 0.05. Uppercase letter(s) indicate differences between main effects whilst, lowercase letter(s) refer to differences between interaction.

Table 9: Main and interactive effects of nitrogen rates, in-row spacing and planting dates on total tubers yield fed^{-1} (tone) of potato, in the summer seasons of 2014 and 2015

		2014				2015			
		N rate(kg fed^{-1})				N rate(kg fed^{-1})			
In- row spacing (cm)	Planting date	150	200	250	Mean	150	200	250	Mean
20	Jan. 15th	11.39^{ef*}	15.06^{cd}	12.85^{de}	13.10^{cd}	15.80^{e}	19.94^{cd}	20.84^{c}	18.86^{c}
	Jan. 30th	16.20^{bc}	15.02^{cd}	20.32^{a}	17.18^{a}	25.51^{a}	27.03^{a}	25.61^{a}	26.05^{a}
	Feb. 14th	15.76^{c}	14.27^{cd}	12.63^{de}	14.22^{c}	7.78^{g}	7.80^{g}	8.51^{g}	8.03^{e}
30	Jan. 15th	9.69^{f}	9.38^{f}	11.20^{ef}	10.09^{e}	18.22^{d}	13.94^{ef}	12.63^{f}	14.93^{d}
	Jan. 30th	16.50^{bc}	12.51^{de}	18.78^{ab}	15.93^{b}	25.14^{a}	23.22^{b}	19.65^{cd}	22.67^{b}
	Feb.14th	11.21^{ef}	11.65^{ef}	13.11^{de}	11.99^{d}	7.30^{gh}	5.81^{h}	5.79^{h}	6.30^{e}
		15.55^{a}	13.95^{a}	14.75^{a}	14.75^{A}	16.37^{a}	18.26^{a}	18.32^{a}	17.65^{A}
		12.37^{a}	12.02^{a}	144.88^{a}	13.09^{B}	16.88^{a}	14.32^{a}	12.69^{a}	14.63^{B}
20	Jan. 15th	10.52^{a}	12.22^{a}	12.03^{a}	11.59^{C}	7.55^{a}	6.81^{a}	7.15^{a}	7.17^{C}
30	Jan. 30th	16.45^{a}	13.77^{a}	19.55^{a}	16.59^{A}	19.33^{a}	19.12^{a}	16.63^{a}	18.36^{A}
	Feb. 14th	13.49^{a}	12.96^{a}	12.88^{a}	13.11^{B}	10.99^{a}	10.94^{a}	10.74^{a}	10.89^{B}
	Mean	13.55^{A}	12.98^{A}	14.81^{A}		15.53^{A}	15.20^{A}	14.41^{A}	

*Values marked with the same letter(s) within the main and interaction effects are statically similar using Revised LSD. Test at probability = 0.05. Uppercase letter(s) indicate differences between main effects whilst, lowercase letter(s) refer to differences between interaction.

(17.18 tons) and in 2015 season (26.05 tons). The effect of 2nd order interaction among the three studied factors on total tubers yield fed^{-1} was significant, in both seasons. The integrated treatment that achieved highest total tubers yield fed-^{1} was seed planting date on Jan. 30 + in-row spacing of 20 cm + N level of 200 and/or 250 kg fed^{-1}.

Increasing N rate over 150 kg fed^{-1} did not reflect any remarkable influence on tubers yield and its components. This result can be discussed on the basis that; as an average of the two seasons, N application at 150 relative to 200 and 250 kg fed^{-1} increased number of tubers plant^{-1} by 0.29 and 2.13%, average tuber weight by 0.22 and 8.23%, tubers yield plant^{-1} by 4.13 and 10.66% and accordingly total tubers yield fed^{-1} increased by 3.28 and 2.91%, orderly. Thus, the increments in total tubers yield fed^{-1} over 150 kg N fed^{-1}were not economically. The favorable influence of in-row spacing 20 than 30 cm on total tubers yield fed^{-1} can be explained on the basis that, as an average of the two seasons, planting seed potatoes at in-row spacing of 20 cm compared to 30 cm

increased number of tubers plant^{-1} and decreased average tuber weight by 14.96 and 12.00%, orderly. The reduction in average tuber weight (12.00%), was not able to compensate the increments in number of tubers plant^{-1} (14.96%) therefore, tubers yield fed^{-1} increased at narrow over wide spacing by 16.66%. The beneficial response of seed planting potatoes on Jan. 30 over Jan. 15 and Feb. 14 on total tubers yield fed^{-1} can be related to tuber yield components. As an average of the two seasons, seed planting date on Jan. 30 increased number of tubers plant^{-1} by 65.35 and 45.33%, average tuber weight by 48.44 and 16.91%, tubers yield plant^{-1} by 126.21 and 74.10% and total tubers yield fed^{-1} increased by 99.60 and 47.57% over seed planting dates on Jan. 15 and Feb. 14, one by one.

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