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# ESTIMATION OF NITROGEN REQUIREMENTS FOR POTATO CROP IN SANDY SOILS OF SAUDI ARABIA

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## ABSTRACT

Two field experiments were carried out during winter seasons of 2000-2001 and 2001-2002 to estimate the optimum N level for growth, yield and quality parameters of potato plants grown on sandy soils under drip irrigation system and arid conditions of central region of Saudi Arabia. Five N levels of 0, 100, 200, 300 and 400 Kg N $ha^{-1}$ were tested.

The results indicated that the fresh and dry matter yields of shoots and tubers as well as the total carbohydrate yield in tuber dry matter significantly increased in form of a quadratic equation curve with increasing of N fertilization rates. The highest fresh and dry matter yields of shoots and tubers as well as the total carbohydrate yield in tuber dry matter were obtained as calculated average N application rate of about 255 Kg N $ha^{-1}$ using the second ploynomial equations in both seasons. While the optimum economic level of N fertilization for growth, yield and total carbohydrate yield was observed at 100 and 200 Kg N $ha^{-1}$ (as average, 150 Kg N $ha^{-1}$) at the two seasons. Shoot and tuber content of N was significantly increased, while P and K content insignificantly increased with N application rates. On the other hand, Shoot and tuber N, P and K uptake by potato plants was significantly increased with increasing N fertilization levels.

Soil salinity (ECe) was insignificantly increased with increasing N fertilization rate, while soil pH was slightly decreased. Available soil N was significantly increased with increasing N application rate. However, increasing N fertilization rate has slight effect on the available soil P and K.

Keywords: N fertilization, shoot and tuber yields of potato plants, total carbohydrate yield, nutrient content, soil chemical properties.

## INTRODUCTION

Soils in the central region of Saudi Arabia are predominantly sandy soils (Al-Omran and Shalaby, 1992). These soils are poor not only in essential plant nutrients but also in organic matter content which is a storehouse for many nutrients, especially nitrogen, in addition to inadequate water retention. Under such severe conditions, the productivity of different crops tends to decrease markedly (Sabrah *et al.*, 1995 and Metwally and Khamis, 1998). Nitrogen is indispensable for the growth and development of all plants and is required in relatively large amounts, especially in marginal soils (El-Shinnawi *et al.*, 1990). Several investigators reported that using nitrogen fertilizers promoted the growth and yield of potato plants in the sandy soils (Ibrahim *et al.*, 1987; Omran *et al.*, 1991 and El-Fakhrani, 1999a) under arid environments. Nevertheless, the excessive application of nitrogen fertilizers may cause environmental pollutions of ground water and health problems. Therefore, optimum rate of nitrogen fertilizers applied to potato crop should be evaluated under sandy soils prevailing in Al-Qassim region of Saudi Arabia. This will assure the bet possible quality and the greatest quantity of the crop produced while keeping the environment out of harm's way.

The objective of this study is to estimate the optimum N level needed *to achieve the best growth, yield and quality parameters of potato plants in* sandy soils under drip irrigation system and arid conditions prevailing in the central region of Saudi Arabia, e. g. Al-Qassim region.

## MATERIALS AND METHODS

Two field experiments were carried out during the winter seasons of *2000–2001 and 2001–2002 at the experimental farm of the* College of Agriculture and Veterinary Medicine, King Saud University, Al-Qassim Branch, Buraydah.The characteristics of the experimental soil were determined according to Page *et al.*, (1982), and shown in Table 1. Each experiment included five nitrogen rates as follows: 0, 100, 200, 300 and 400 Kg N $ha^{-1}$ . Urea (46% N) was used as a source for nitrogen. Treatments were arranged in a randomized block design with three replicates in 15 drip lines, 1 m apart and 20 m long, three drip lines for each treatment were used. Potato seeds, CV. Spunta in the first season (2000–2001) and CV. Mondial in the second season (2001–2002), were sown on 19 and 24 October in 2000 and 2001, respectively. Potato seeds, CV. Mondial were used in the second season because CV. Spunta seeds were not available. The potato seeds were obtained from Hettema Company, P. O. Box 99, 8300 AB Emmeloord, Holland. Sowing was done in hills 30 cm apart at a 10 cm depth. Prior to sowing the total dose of phosphorus at 60 Kg P $ha^{-1}$ was applied as triple superphosphate (20% P). Potassium was added as potassium sulphate (40% K) at the rate of 200 Kg K $ha^{-1}$ and applied to the soil in two equal doses. Nitrogen fertilizer was added to the soil in three equal doses. The first dose of K and N fertilizers was applied after germination, the second dose was applied after three weeks from the first dose and the third dose of N was applied after three weeks from the second dose. Ordinary cultivation practices and drip irrigation with water with characteristics shown in Table 2 were applied. At harvest time, the number *of plants, shoot and tuber fresh* weights per drip line, then average shoot and tuber fresh weights per plant were determined. The dry weight was determined by drying at $70^0$C to a constant weight. Nutrients content (N, P and K) in shoots and tubers were determined according to Chapman and Pratt (1961). Total carbohydrate content of tubers dry matter was determined colorimetric by a spectrophotometer according to Dubois *et al.* ( 1956 ). Mixed disturbed *surface sample (0–30 cm, depth) from each drip line* (each N treatment) was taken after harvesting and used for determination of soil pH and electrical conductivity (ECe) in the saturation paste extract and the soil available nutrients of N, P and K were determined according to Page *et al.* (1982).

**Table 1: Characteristics of experimental soil**

| Particle size Distribution (%) | | | Tex-Tural class | PH* | ECe* ($dSm^{-1}$) | Ion concentration* ($meq\ l^{-1}$) | | | | | | $CaCO_3$ (%) | Organic Matter (%) | Soil available Nutrients ($mg\ Kg^{-1}$ soil) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sand | Silt | Clay | | | | $HCO_3^-$ | $Cl^-$ | $SO_4^=$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | | | N | P | K |
| 96.5 | 1.1 | 2.4 | Sand | 7.81 | 1 72 | 2.69 | 6.81 | 7 65 | 8.15 | 1.86 | 7.14 | 3.72 | 0.42 | 54.3 | 6.5 | 70.0 |

* Measured in saturation paste extract

**Table 2 : Chemical analysis of water used for irrigatio**

| pH | ECw ($dSm^{-1}$) | Ion concentration ($meq\ l^{-1}$) | | | | | | | Adj.SAR |
|---|---|---|---|---|---|---|---|---|---|
| | | $HCO_3^-$ | $Cl^-$ | $SO_4^=$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | |
| 6.92 | 1.39 | 1.95 | 5.75 | 6.18 | 4.17 | 1.74 | 7.78 | 0.19 | 8.60 |

## RESULTS AND DISCUSSION

### Plant growth

Figures 1 and 2 show the effect of N fertilization on growth and yield of potato plants for the two stutied seasons. The fresh and dry matter yields of shoots and tubers significantly increased in form of a quadratic equation curve with increasing of N application rates. This increase may be due to that N increased photosynthetic area and consequently increased photosynthates (Abd El-Gawad *et al.*,1997). These results are in harmony with those obtained by Ibrahim *et al.* (1987); Omran *et al.* (1991) and El-Fakhrani (1999b) who found that N fertilization had significant effect on the growth and yield of shoots and tubers of potato plants. The differences between the curves in figures 1 and 2 may be attributed to the potato cultivar and environmental conditions. The calculated average N fertilization rate using the second ploynomial equations was about 260 Kg N $ha^{-1}$ for highest fresh and dry matter yields of shoots and tubers at the two seasons. On the other hand, the optimum economic level of N fertilization for growth and yield of potato plants was observed at 100 and 200 Kg N $ha^{-1}$ (as average, 150 Kg N $ha^{-1}$) in both seasons (Figures 1 and 2).

### Carbohydrate yield

The relationships between total carbohydrate yield in potato tuber dry matter and the N application rates at the two seasons are shown in figure 3. These results demonstrated clearly that the total carbohydrate yield in potato tuber dry matter significantly increased in form of a quadratic equation curve with increasing of N fertilization rates as compared to the control. This may be attributed to the positive effect of N on photosynthetic area and consequently on photosynthesis (Abd El-Gawad *et al.*,1997). These results coincide with those reported by many investigators using various plant species (Abd El-Gawad *et al.*,1997; El- Fakhrani and Abdel Magid,1997 and El-Fakhrani,1999). The highest total carbohydrate yield in tuber dry matter was obtained as calculated average N application rate of about 250 Kg N $ha^{-1}$ using the second ploynomial equations in both seasons. In addition, the optimum economic level of N fertilization for total carbohydrate yield was observed at 100 and 200 Kg N $ha^{-1}$ (as average, 150 Kg N $ha^{-1}$) (Figure 3).

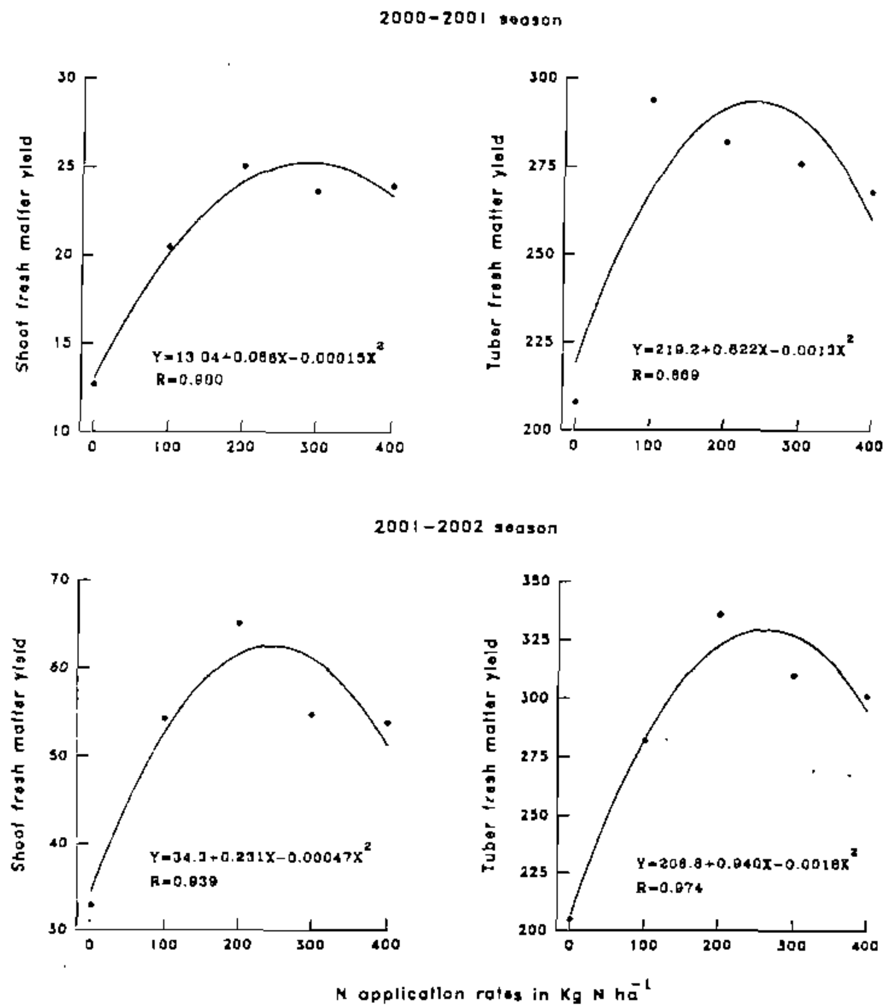


Fig. (1): Relationships between N fertilization and shoot and tuber fresh matter yields (g/plant) of potato plants at two seasons.

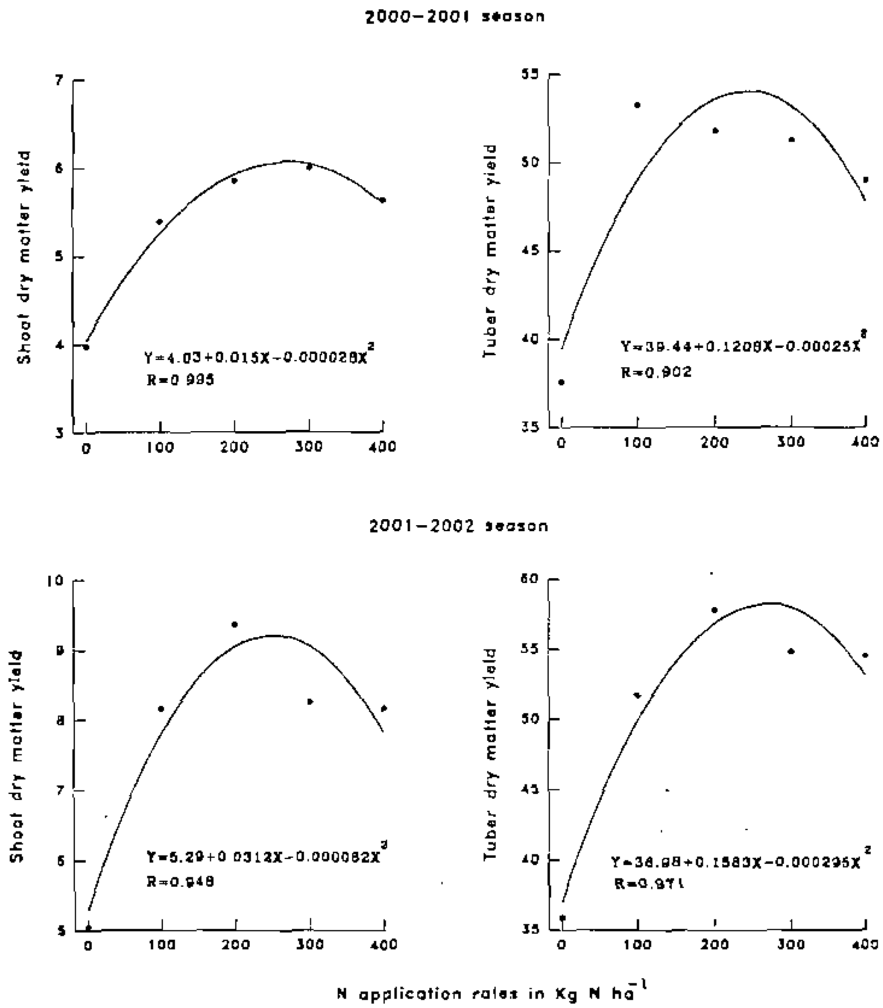


Fig. (2): Relationships between N fertilization and shoot and tuber dry matter yields (g/plant) of potato plants at two seasons.

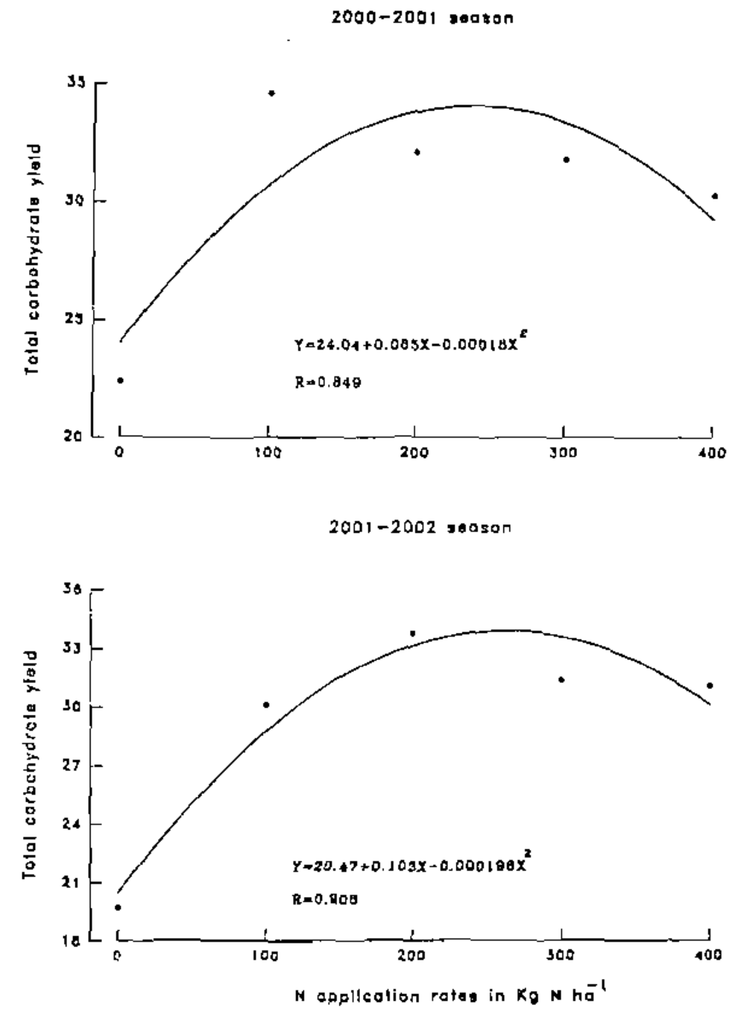


Fig. (3): Relationships between N fertilization and total carbohydrate yield (g/plant) of dry potato tubers at two seasons

**Nutrient content**

Table 3 shows the effect of N fertilization on the concentration of N, P and K in shoots and tubers of potato plants at the two seasons. It can be observed that the concentration of N in shoots and tubers at the second season was greater than that in shoots and tubers at the first season. This may be due to the potato cultivar.

**Table 3 : N , P and K contents (%) In shoots and tubers as affected by nitrogen fertilization in the two seasons.**

| Nitrogen Levels | First season | | | | | | Second season | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shoots | | | Tubers | | | Shoots | | | Tubers | | |
| (Kg N ha$^{-1}$) | N | P | K | N | P | K | N | P | K | N | P | K |
| 0 | 2.11 | 0.18 | 4.50 | 0.98 | 0.19 | 2.52 | 4.12 | 0.21 | 3.55 | 2.23 | 0.16 | 1.83 |
| 100 | 2.66 | 0.18 | 4.52 | 1.95 | 0.19 | 2.60 | 4.57 | 0.21 | 3.57 | 2.61 | 0.16 | 1.88 |
| 200 | 2.86 | 0.18 | 4.53 | 2.09 | 0.20 | 2.67 | 4.90 | 0.22 | 3.72 | 2.84 | 0.17 | 1.92 |
| 300 | 2.88 | 0.18 | 4.62 | 2.25 | 0.20 | 2.72 | 4.97 | 0.23 | 3.75 | 3.80 | 0.17 | 2.03 |
| 400 | 2.87 | 0.19 | 4.83 | 2.30 | 0.20 | 2.77 | 5.31 | 0.23 | 4.17 | 4.34 | 0.17 | 2.20 |
| LSD(p= 0.05) | 0.46 | 0.02 | 0.82 | 0.38 | 0.03 | 0.26 | 0.96 | 0.03 | 0.72 | 1.02 | 0.02 | 0.38 |

Moreover, the obtained results indicate that increasing N application rates significantly increased the concentration of N, while they had insignificant effect on the P and K content in shoots and tubers at the two seasons. These findings are in good agreement with those obtained by Ibrahim *et al.* (1987); Omran *et al.* (1991) and El–Fakhrani (1999b) who found that the addition of N fertilization to soil increased N content in potato plants.

**Nutrient uptake**

The effect of N fertilization on the uptake of N, P and K by potato plants is shown in Table 4. It can be observed that the uptake of N, P and K in tubers was more higher than that in shoots. This may be attributed to an increase in tubers dry matter (Figure 2). Also, the obtained results indicate that the uptake of N, P and K in shoots and the N uptake in tubers at the second season were greater than that in shoots and tubers at the first season. Conversely, the uptake of P and K in tubers at the first season was higher than that in tubers at the second season. This may be due to the decrease in P and K content of tubers at the second season (Table 3).

**Table 4 : N , P and K uptake (mg plant$^{-1}$) by shoots and tubers as affected by nitrogen fertilization inthe two seasons.**

| Nitrogen Levels | First season | | | | | | Second season | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shoots | | | Tubers | | | Shoots | | | Tubers | | |
| (Kg N ha$^{-1}$) | N | P | K | N | P | K | N | P | K | N | P | K |
| 0 | 84 | 7.2 | 179 | 359 | 73 | 945 | 208 | 10.4 | 179 | 820 | 57 | 658 |
| 100 | 143 | 9.5 | 242 | 1041 | 103 | 1382 | 376 | 17.2 | 289 | 1387 | 80 | 965 |
| 200 | 168 | 10.5 | 265 | 1079 | 105 | 1377 | 472 | 20.1 | 353 | 1644 | 97 | 1114 |
| 300 | 173 | 10.8 | 276 | 1176 | 103 | 1400 | 410 | 19.3 | 315 | 2073 | 91 | 1102 |
| 400 | 163 | 10.6 | 271 | 1126 | 96 | 1355 | 432 | 19.1 | 343 | 2347 | 95 | 1192 |
| LSD(p= 0.05) | 55 | 2.5 | 60 | 374 | 20 | 307 | 225 | 7.3 | 151 | 736 | 26 | 314 |

Moreover, the results demonstrate that there was a significant increase in the N, P and K uptake of shoots and tubers at the two seasons caused by different N fertilization rates relative to the control. Similar results were obtained by Faiyad *et al.* (1991); El–Tilib *et al.* (1995); El–Fakhrani and Abdel Magid (1997); Metwally and Khamis (1998) and El–Fakhrani (1999b and 2000) who found that the application of nitrogen fertilizer caused an increase in N, P and K uptake by different plants.

**Soil pH and soil salinity**

The effect of N fertilization on the soil pH and electrical conductivity (ECe) is shown in Table 5. It can be observed that as the rate of N fertilization increases the soil pH value slightly decreases, and the opposite was observed true regarding the ECe particularly at the high levels of N fertilization (300 and 400 Kg N $ha^{-1}$) in both seasons. Feigin (1985) who reported that excessive application of N fertilizers to the soil increased the ECe of the soil solution in conformity with those obtain these results. Mostafa *et al.* (1992) found a slight decrease in soil pH as a result of increasing soil salinity. Moreover, El-Fakhrani (1999a) found, in pot experiment, that the addition of urea and calcium nitrate fertilizers significantly decreased the soil pH values, while the ECe values increased especially at high levels as compared to the control.

**Available soil nutrients**

Table 5 depicts the effect of N fertilization on the availability of soil N, P and K after harvesting of potato plants in the two growing seasons. It is evident that available soil N after harvesting of potato plants in the first season was more higher than that in the second season. This may be attributed to an increase in N uptake of shoots and tubers at the second season (Table 4). In addition, table 5 indicates that available soil N was significantly increased with increasing N fertilization rate as compared to the control in both seasons. These results are in good agreement with those obtained by El–Sherbieny *et al.* (1989) and El-Fakhrani (1999b and 2001) who reported that application of N fertilizers and organic manure to soil led to raising the available soil N. The reduction in the available soil P with increasing N fertilization rates may be attributed to the promotive effect of N fertilization on the P uptake by potato plants in both seasons (Table 4). On the other hand, table 5 reveals that increasing N application rates had slight effect on the available soil K in the two seasons.

**Table 5: pH, electrical conductivity (ECe, dS $m^{-1}$) and Available N , P and K (mg $Kg^{-1}$) in the experimental soil after harvesting of potato plants as affected by nitrogen fertilization in the two seasons.**

| Nitrogen Levels (Kg N $ha^{-1}$) | First season | | | | | Second season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pH | ECe | Soil available nutrients | | | pH | ECe | Soil available nutrients | | |
| | | | N | P | K | | | N | P | K |
| 0 | 8.10 | 1.32 | 41.1 | 31.5 | 90 | 8.01 | 1.26 | 10.4 | 18.7 | 88 |
| 100 | 8.08 | 1.45 | 49.1 | 28.8 | 100 | 7.97 | 1.31 | 16.1 | 17.9 | 84 |
| 200 | 7.82 | 1.47 | 54.1 | 24.9 | 88 | 7.86 | 1.39 | 17.3 | 17.1 | 81 |
| 300 | 7.81 | 1.51 | 68.6 | 23.2 | 88 | 7.83 | 1.48 | 18.7 | 14.5 | 87 |
| 400 | 7.63 | 1.61 | 80.1 | 23.5 | 90 | 7.67 | 1.55 | 19.4 | 15.4 | 79 |
| LSD(p= 0.05) | 0.56 | 0.35 | 11.0 | 8.7 | 28 | 0.51 | 0.46 | 4.6 | 5.8 | 17 |

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# تقدير الاحتياجات النيتروجينية لمحصول البطاطس في الأراضي الرملية بالمملكة العربية السعودية

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أجريت تجربتان حقليتان خلال شتاء موسمي ٢٠٠٠ – ٢٠٠١ و ٢٠٠١ – ٢٠٠٢ وذلك لتقدير مستوى التسميد النيتروجيني الأمثل لنمو ومحصول ومقاييس الجودة لنباتات البطاطس النامية في أراضي رملية تحت نظام الري بالتنقيط والظروف الجافة للمنطقة الوسطى بالمملكة العربية السعودية. اختبرت خمس معدلات من التسميد النيتروجيني هي:صفر ، ١٠٠ ، ٢٠٠ ، ٣٠٠ و ٤٠٠ كجم نيتروجين / هكتار.

أوضحت النتائج أن هناك علاقة معنوية لا خطية بين محصول المادة الطازجة والجافة للمجموع الخضري والدرنات وكذلك الكمية الكلية للمواد الكربوهيدراتية في المادة الجافة لدرنات البطاطس والتسميد النيتروجيني . وتشير النتائج إلى أن أعظم محصول للمادة الطازجة والجافة للمجموع الخضري والدرنات وكذلك الكمية الكلية للمواد الكربوهيدراتية في المادة الجافة للدرنات يمكن الحصول علية عندما يكون متوسط معدل إضافة النيتروجين حوالي ٢٥٥ كجم نيتروجين / هكتار المحسوب باستخدام معادلات الدرجة الثانية لكل من الموسمين ، بينما لوحظ أن مستوى التسميد النيتروجيني الأمثل لنمو ومحصول البطاطس والكمية الكلية للمواد الكربوهيدراتية كان ١٠٠ و ٢٠٠ كجم نيتروجين / هكتار ( كمتوسط ١٥٠ كجم نيتروجين / هكتار ) في الموسمين . ولقد أظهرت النتائج أن محتوى المجموع الخضري والدرنات من النيتروجين يزداد معنويا بزيادة معدلات إضافة النيتروجين ، بينما محتوى الفوسفور والبوتاسيوم لا يزداد معنويا ً. ومن الناحية الأخرى فقد زاد امتصاص كل من النيتروجين والفوسفور والبوتاسيوم معنويا بواسطة المجموع الخضري والدرنات لنباتات البطاطس بزيادة معدلات التسميد النيتروجيني .

وأوضحت النتائج أن ملوحة التربة لا تزداد معنويا مع زيادة معدل التسميد النيتروجيني ، بينما انخفض رقم pH التربة انخفاضا طفيفا . كما لوحظ أن النيتروجين الميسر في التربة بعد الحصاد يزداد زيادة معنوية مع زيادة معدل إضافة النيتروجين . ولكن زيادة معدل التسميد النيتروجيني كان له تأثيرا طفيفا على كل من والفوسفور والبوتاسيوم الميسر في التربة .