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Maximizing crop water productivity from the water unit: Effect of N and P fertilizers rates on the peanut plant growth and yield parameters under different water stress

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Abstract---Egypt is currently suffering from the vast increase in population that is increasing water consumption whether for domestic use or by other sectors especially, the agricultural one, which consumed more than 80 % of the water income. Experiment was conducted under drip irrigation system in the sandy soils of the experimental Farm of the National Research Centre, El-Nubaria, El-Behera governorate. The aim of this work is to study the effect of the N (0, 25; 50 kg/fed) and P (0, 10, 20, 30) fertilizers at different rates on the growth, yield parameters and crop water productivity (CWP) of peanut plant. Resulted data showed that application of N and P at the rates of and kg/fed, respectively on peanut crop to increase yield and enhance quality. CWP increased in the current experiments in the following order of 60>80>100 % ETo despite the reduction in crop yield. The quality attributes of oil and protein contents significantly improved by irrigation levels, N and/or P fertilizers application rates and their interactions. Increased rates from 0 to 25 (P) and from 0 to 50 (N) kg/fed associated with increase represented in % as follows 0.8, 0.5,5.9,16.7,1.4,1.4,12.0% and 1, 0.7,7.4,35.9,0.6,10.7,11.5%

(plant height, pod weight/plant, seed weight/plant, no of pods/plant, no. of seed / plant) and water use efficiency, respectively. The rate of increase after 30 kg/fed where higher than 20 and 10 kg comparing with control.

Keywords---nitrogen, phosphorus, fertilizers, crop water productivity.

Introduction

Agricultural products increased progressively relative to the increased population. However, the availability of water for agriculture has been declining due to the increasing demand for water for nonagricultural sectors (Tilman et al., 2011). Shortage of irrigation water is seriously affecting agricultural production, particularly in arid and semi-arid regions. In the light of diminishing water resources for agriculture and increasing demand for crop production, irrigation strategies need to be devised to maximize crop water productivity (CWP). Water scarcity in Egypt is a major challenge in agriculture development. Without maximizing the CWP by the crops to save water, developments in the agriculture sector will be limited.

Deficit irrigation which involves an application of the amount of irrigation water lesser than the full crop evapotranspiration (ET) is emerging as an important technique to enhance crop water productivity (Geerts and Raes, 2009). It had been reported that deficit irrigation increased CWP with considerable saving of irrigation water in many crops, particularly in arid and semi-arid regions (Singh, et al., 2010 and Wang; Xing 2017). Li et al. (2016) reported that agronomic practices influenced WP more than climatic factors; and from among various agronomic management, fertilizer rate and irrigation contributed 42.3% and 32.8%, respectively to the increase of CWP . Adequate nutrient management is an important determinant of WP. Deficit irrigation and cultivating a drought-tolerant crops are the main strategies for water-saving under these conditions with optimum fertilization. Deficit irrigation is a good tool to increased CWP and reduce water supply costs (English et al., 1996). Water deficit stress negatively affects plant physiology and metabolism (Zhu, 2002). The severity of water deficit stress on plant function can range from mild to severe depending on the degree and extent of the stress (Jaleel and Llorente, 2009). Water deficits can limit growth and influence a host of physiological functions in plants to a greater extent than any other environmental factors.

Nitrogen (N) is one of the most important limiting factors for crop production in many regions of world (Kheira, 2009), and the efficiency of N-fertilizer is low (30–50%), Bishi et al 2015 which increases the cost of production and causes environmental problems including soil quality deterioration and water contamination. Phosphorus (P) is one of the most widely occurring nutrients for development and growth of crops. P plays an essential role not only in synthesis of proteins, nucleotides, and enzymes, but also in photosynthesis and other physiological and biochemical metabolisms (Marchner 1993). However, the fact is that phosphorus is one of the main limiting factors for the world wheat production (Michael and Tilman 2017). Application of P fertilizers could be a most

direct and efficient approach to increase crop production. A viable strategy to overcome the problem of low P availability will be through proper management practices such as the application of phosphorus-based fertilizer/manure to increase P use efficiency (Ortiz-Monasterio et al. 2002). Many researchers showed positive effect of phosphorus fertilization on peanut, which may require P fertilizer in the range of 20 to 50 kg P ha⁻¹ (FAO, 2018). Significant increases were achieved in faba bean yield and its attributes by increasing phosphorus fertilization rate up to 45kg P₂O₅ /fed (El-Habbasha et al., 2007).

Peanut (*Arachis hypogaea* L.) is a major legume crop in arid and semi-arid regions of the world (Kheira, 2009). Its seed is rich in oil (48–50%), protein (25–28%), carbohydrates (20–26%), and contains several minerals, vitamins, dietary fibers, phytosterols, and flavonoids Bishi et al., 2015. Whereas, peanut yields are low and variable under arid and semi-arid conditions. Water deficits negatively affect peanut growth, depending on the stage of crop growth and the degree of drought stress (Roy et al, 2006. FAO, 2018). Drip irrigation is the delivery of low amounts of water at a high frequency usually limits water evaporation and drainage, thus representing a high water use efficiency, which has been confirmed experimentally (Sun et al. 2013).

Sandy soils are generally regarded as very fragile concerning agricultural production due to their very low nutrients and organic matter content (Ebtisam and Abd El-Hady, 2015) found that application of soil conditioners (bentonite) to sandy soil combined with increase in soil moisture content in all studied depths, especially the upper layers. Therefore, the main objective of this work is to study the effect of the N and P fertilizers and their rates on the growth and yield parameters and crop water productivity of peanut plant.

Materials and Methods

Field experiments were carried at National Research Centre Farm for Research and Production, Nubaria district, El-Behiera Governorate, Egypt, during summer of 2020 season. Peanut (*Arachis hypogaea* L.) Giza 45, were grown in 25 cm hills with 3 to 4 seeds / hill using dry seeding on one side of the hills during the last week of April in the every growing season. Date of planting is 15th of April, 2020 in which 45 Kg/ fed with homogeneity in size and weight were cultivated in density were planted in both lateral 15 cm among in two direction. The study extended till the 10th of October, 2020. The distance between lines was 70 cm and 15 cm between plants. Additional Agricultural practices have been maintained, as is usually in peanut fields in harmony with the recommendations of the Ministry of Agriculture, excluding the factors in reading. The drip irrigation was installed in the form of lateral lines (30 m long) with built-in drippers (discharging 4 liter/h) of 0.3 m apart and 0.7 m between laterals.

Soil preparation

Before each experiment the following procedures were carried out:

- Super phosphate (15 % P_2O_5) and ammonium nitrate (33.3 % N) and elemental sulfur were applied during soil preparation at rates 200, 50 and 150 kg /feddan (feddan = 4200 m²) following the experimental treatments.
- Well decomposed farm yard manure (FYM) was added to the experimental area before planting and well mixed 10 ton/fed (23 % moisture content), respectively.
- Control of weed was done by manual method, for 3 times. In the end of cultivation season, 2 middle-line was chosen from each plot taking as examined samples.

Irrigation process

Irrigation process was carried out twice a week according to the obtained evapotranspiration (ET) of the farm meteo station by 100, 80 and 60 % from ETo and total water consumed during growing season were 3175, 2540 and 1910 m³/season for peanut experiment, and 3266, 2615 and 1960 m³/ season for sugar beet experiment, respectively.

Soil physiochemical properties

Soil is sand in texture (84.3, 12.5; 3.2 % for sand, silt and clay respectively).The experimental soil were sandy loam with pH (8.13), electrical conductivity (0.82 dS⁻¹) in soil paste extract, CaCO₃ (3.24 %) determined by Scheibler-calcimeter (Soil Survey Staff, 2003) and organic matter (0.65 %) was determined after (Nelson and Sommers, 1982). Dry sieving was used to determine aggregate more or less than 2mm. Soil water retention (determined after, Klute, 1986) at 0.1 (FC) and 15.0 (WP) bars were estimated 12. According soil available water was calculated by subtracting FC -WP and the values were 16.5, 5.7 and 10.8 % on weight base, respectively.

Determinations related to peanut crop as follow:

After 130 days of cultivation random samples of 5 guarded plants were taken from each piece to establish the next characters:

- Height of plant (cm). Marketable pods per plant were picked and let to dry up normally, then, the following characters were determined:
- Number of pods/plant.
- Pods weight/plant (g).

Samples of twenty dry pods were taken to determine the following characters:

Whole plants in each plot were harvested and left to dry on air, then they were threshed and the seeds (which were at 13 % moisture) were weighted (kg), Pod weight (g), Number of seeds/plant, Seeds weight/plant (g), 100 seed weight (g), Seed yield (kg/fed), oil and Protein in seeds (%). Oil and protein content of groundnut

meal were determined by standard methods i.e. Soxhlet and Kjeldahl method, respectively. Phosphorus was applied during soil preparation in the rate mentioned in the design of the experiment (calcium super phosphate, 15 % P_2O_5). Whereas, N fertilizer applied 20% relative to the experimental design during soil preparation (ammonium sulfate 22.5 %N) and three equal doses 30, 50; 70 days from planting in ammonium nitrate , 33.5% N). Potassium sulfate (50 % K_2SO_4) was added (100 kg) in 4 equal doses: the 1st during soil preparation, 2nd before flowering and the last two after a month and 15 days among true irrigation system. Also, Phosphoric acid was fertigated during the first 20 days of planting to activate root distribution.

Statistical analysis

Data were analyzed by SAS software package (SAS Institute, 2001). Collected data under each irrigation system were subjected to normal statistical analysis according to Dospikhov, B.A. (1984). Treatment mean comparisons were done using least significant difference (LSD) at 5% level of probability.

Results

Data manifested in table (1) showed the effect of the N and P fertilization rates and their interactions on peanut the plant grows character (plant height, pod weight/plant, seed weight/plant, no of pods/plant, no. of seed / plant) and water use efficiency of the under different water stress 100, 80, and 60 % from ETo. Resulted data reported that control treatment of both studied fertilizers (P and K) recorded the lowest values of the studied peanut plant growth characters especially under 60% of water stress, except for water use efficiency where the opposite was true. From the other side, increase N and/or P fertilizer individually or in combination was associated with increase in the values of the examined peanut plan to growth characters values under 100% followed by 80% and 60% water stress.

With respect to the water use efficiency, data on hand revealed that that decreases the amount of water application true irrigation treatment for 100 to 80 and 60%, associated with increase water use efficiency value. Also data found that reduced the water stress by 20% (100 to 80 % from ETo) lead to increase water use efficiency by 9.1 and by 40 % (100 to 60% from ETo) by 31.1%. Delta in table (3) showed the effect of P fertilizer application rate 0, 10, 20; 30 kilogram/fed under different water stress (100, 80, 60%). Resulted data pointed out that the highest values were found at 30 kg and over 100% followed by 80% navigation regime treatments. Meanwhile the lowest values recorded at control and under 60% water stress.

Regardless irrigation treatments, data on hand (table 3) indicated that increase P application rate combined with increasing in the most studied peanut plant characters. Also, resulted data indicated that after 10 and 20 kg P fertilizer led to slightly increase in the examined peanut plant growth character of peanut plant compared with control. Meanwhile circular gram P fertilizer led to increase in the blend growth characters values, significant with the other rates and control too. The rate of increase in the percentage were 2.2, 17.3, 30, 89, 3.2 and 11.0% for P

such as (plant height, pod weight/plant, seed weight/plant, no of pods/plant, no. of seed / plant) and water use efficiency, respectively.

Data in tables (3) showed the effect of P rates in kilogram with that then on the oil and protein % and plant weight and NPK content in peanut shoot under different water stress. The lowest and the highest values of the above mentioned parameters were recorded at control under 60% water stress and the opposite was true at 100% water stress with 30 kg fertilizer respectively. Data in Table (4) pointed out that increasing P rates associated with increase in most previous studies yield parameters and NPK content. In view of point, the highest P rates have a positive change while reduced water stress from 100 to 80 and to 60 % lead to dramatically decrease those values.

Regardless fee rates, death in table three short that decrease water stress from 100 to 80% lead to increase in the study in the barometers by 1.1, 1.3, 12.7, 2.6, more into 4, 0.7% for oil protein, seed yield, respectively where as it decrease the by 3.8 1.1 and 1.21 % and increase by 0.7% for plant weight and NPK content respectively. Whereas, the rate of a change in percentage where minus -3.4, 2.1, 21.3, - 9.4, 11.8, 12.5 and 1.6% in same previous sequence comparing 60 % with 100% navigation regime. According to the P rates effect on the peanut plant growth characters, data on hand showed that there is a slightly increase in their values when comparing 10 kg P with control. That range over there increase in percentage when comparing 20 and 30 kg P fertilizer ranged from 1.0% to 1.4% of oil content and P content, respectively.

Data manifested in table 4 that showed the effect of the N rates (0, 25 and 50 kg per fed.) on the peanut plant characters (plant height, pod weight/plant, seed weight/plant, no of pods/plant, no. of seed / plant) and water use efficiency under different education regime 100, 80, 60%. The lowest values of the peanut characters where recorded at 0 N kg/ fed under 60% water stress and highest one where obtained at 30 kg P under 100% water stress. Regarding to the effect of water stress treatments on the peanut growth characters (plant height, pod weight/plant, seed weight/plant, no of pods/plant, no. of seed / plant) and water use efficiency, data noticed that decreasing irrigation rate by 20% for 100 to 80 will send cost a reduction in peanut grocery and buy one, one, one, one will send and one, in tonight, going to eat, going tonight, going to eat will send respectively if navigation treatment decreased by 40% for 100 to 60%. These increases with expressed in percentage and recorded as follows: 5.0, 5.1, 12.6 and 2.1% and 08, 7.5, 8.6, 21, 4.7, 3.0 will send in same previous sequences (Table 3).

Regarding to the data in table 5 which represented the effect of N rates on the sum dinner yield parameters and NPK content in being a shoot under different water stress, data on hand revealed that the highest values of the (plant height, pod weight/plant, seed weight/plant, no of pods/plant, no. of seed / plant) and water use efficiency were recorded with increasing in rates (30 kg) under 100% water stress, the lowest one where observed 0 kg N under 60% water stress. Regardless N rates effect , reduction in irrigation amount by 20 % and 40% for 100 to 80 % and from 100 to 60 % have positive effect on the oil and protein content and values reach with and NPK content in shoot. This increase and

decreased where represented in percentage as follow- 1.1, -1.3, -12.7,- 14,- 1.21; 0.7% and 3.4,-2.1,-21.4,-14.2,11.8,12.5;1.6% , respectively.

According to the effect of enriched on the oil and data on hand indicated that increasing in rates associated with increase in most of the studies yield parameters of which represented in percentage as follow 59, 08, 0.5, 59, 1.4, 1.5, 12% and 1, .7, 7.4, 35.9, 0.6, 10.7; 1.6% for oil; protein content and values reach with and NPK content in shoot at 25 and 50 kg N, respectively. With respect to the interaction effect of N and P fertilizer rates on the (plant height, pod weight/plant, seed weight/plant, no of pods/plant, no. of seed / plant) and water use efficiency, data in table 6 showed that the lowest values were recorded at control of both N and P and the highest values were attended at 50 kg N and 30 kg P. Regarding to the in effect, that enhanced revealed that increase in rates by 50% from 0 to 25 kilogram and from 25 to 50 kg/ fed, induced and increase for all started being blend gross characters which put in percentage as follow point seven, five, 5.1, 12.6, 2.4, 2. 49% and 28, 7.5, 8.6, 221.6, 4.7, 3.1; 7.9%, respectively. From the other side, the effect of the rates that increase the values, the best rate was 30 kg in percentage 2.2, 17.3, 30.0, 8.9, 3.1, 11.1% compared with control (0 kg P) , respectively.

Also, it is clear to mention that increasing N and/or P lead to increase oil; protein content and values reach with and NPK content in shoot whereas the lowest values will found at untreated treatment (control). Zhu (2002) reported that high P efficiency resulted in leaf area index, increased chlorophyll content and photosynthetic rate, and stable acid phosphatase activity to accumulate more dry matter, which explained that the optimum P fertilizer increased yield and improved quality of wheat. Drought stress imposed from flowering to start of seed growth was shown to be important for both yield and quality. Moursi, et al., (2014) indicated the highest mean values of CWP was recorded under (55 % depletion AW), but the lowest mean values were recorded under (85% depletion AW) under experimental conditions. This confirms the earlier conclusions of Nageswara et al. (1995) that maximum yields of peanut can be achieved with decreased irrigations during the early phase. Excessive irrigations promote vegetative growth at the expense of reproductive growth (100 % ETo).

Regarding to the increase in rates from 0 to 25 and from 0 to 50 kg/fed associated with increase represented in % as follows 0.8, 0.5,5.9,16.7,1.4,1.4,12.0% and 1, 0.7,7.4,35.9,0.6,10.7,11.5% (plant height, pod weight/plant, seed weight/plant, no of pods/plant, no. of seed / plant) and water use efficiency, respectively. Concerning P effect alone, data on hand pointed out that all studied peanut plant characters slightly enhanced with increasing rates. The increase in percentage were 1.1,1.6,1.7,30.9,19.8,25.6;15.1% (10kg/fed), 2.3,2.9,5.1,42.1,20.4,23.4,22.4% (20kg/fed), 4.0,4.3,11.3,91.4,20.1,41.2; 26.7% (30kg/fed) for oil; protein content and values reach with and NPK content in shoot, relative to untreated one, respectively. Also, it is clear to mention that the rate of increase after 30 kg/fed where higher than 20 and 10 kg comparing with control. Where they gave about 100% increase for most studied peanut yield parameters. The quality attributes of kernel measured in terms of oil and protein contents significantly affected by irrigation levels, N and/or P fertilizers application rates and their interactions (Table 2). A significant increase in oil

contents were recorded up to application of 25 Kg N under all irrigation levels. The protein content was enhanced with a reduction in irrigation amount. The N application enhanced protein content.

Resulted data are in agreement of those obtained by Nageswara et al. (1995) showed that decreased irrigation during the early phase was even beneficial. In a review of the studies on water relations of groundnut. The excessive use of irrigation and N fertilizer leads to reduction in CWP and economic benefits along with many environmental problems. Therefore, suitable irrigation and N and P-fertilizer regimes are needed for augmenting water and fertilizer use efficiencies for sustainable peanut production. The effects of different irrigation treatments levels with varying N and /or P rates on CWP, yield, quality, and economic benefit remained unclear. The information on integrated use of irrigation treatments and N rates relating to suitable irrigation and N fertilization rates to achieve high yield, economic benefit, and CWP with better quality and saving of irrigation water is very limited. In dry soils, root growth is much less depressed than shoot growth and there is typically an increase in the root to shoot dry weight ratio in response to drought stress (Marschner 1995).

The results showed that soil application of P fertilizer levels significantly increased the average values of plant growth parameter, yield and its components and chemical constituents of faba bean plant as well as available N, P and K of soil after harvesting stage (Fouda, 2017). Whereas, Hawi et al., (2015) recommended for optimum growth and yield of maize and also save the precious soil, money and time of resource poor small holder farmers, of the study area. Plants rarely full fill their maximum yield potential due to unsuitable environment, such as water shortage, climate change and nutrient deficiency (Farid Hellal, et al 2019), who added that drought stress is considered to be one of the largest, single causes of crops yield loss in Egypt. Data on seed quality indicate that moisture stress imposed proved beneficial since it resulted in increased seed weight, oil and protein contents, and higher shelling percentage (proportion of seed to pod weight). Higher protein and oil contents are associated with better seed quality. The total water use of groundnut is controlled by one or more of the following: climatic, agronomic and varietal factors (Nageswara Rao et al., 1995). They added that due to peanut is grown under widely different moisture regimes, irrigations can be withheld during much of the vegetative period without any apparent effect on pod yield.

Conclusions

Data presented in this study that maximum yields of groundnut and improved quality of seeds could be ensured with limited supplemental irrigations, taking into consideration the growth stages sensitive to drought stress. Groundnut showed a remarkable tolerance to drought stress from emergence to peg initiation, and benefits from this drought stress when additional irrigations water are given in the later growth phases. The growth, yield components and yield decreased with a reduction in irrigation and N application rates. The effects of N application rates on growth, yield components and yield were modified with irrigation levels. The 30 kg N /fed under 100% irrigation and irrigation treatment 10 had greater ($P < 0.05$) growth and yield components than other treatments.

The high rate of the N fertilizer under irrigation treatment 80% had greater biomass yield and pod yield than other treatments.

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