Nile Valley University Publications
Nile Journal for Agricultural Sciences (NJAS)
(ISSN: 1585 – 5507)
Volume 06, No. 01, 2021
http://www.nilevalley.edu.sd

Research paper

Enhancing Faba bean (*Vicia faba* L.) Productivity and Seed Quality Using Chemical Fertilizers in High Terrace Soil in the River Nile State, Sudan

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Abstract

Experiments were conducted at the Hudeiba Research Station Farm in the winter seasons of 2017/ 18 and 2018/ 19. The objectives were trying to improve faba bean production and seed quality using chemical fertilizers (nitrogen, phosphorus and potassium). The treatments consisted of eight fertilizers (nitrogen phosphorus, potassium, nitrogen + phosphorus, nitrogen+ potassium, potassium+ phosphorus and nitrogen+ phosphorus +potassium and control, 21kg N/ha,43kg P_2O_5/ha and 45.22kg K_2O/ha). The treatments were arranged in randomized complete block design (RCBD) with four replicates. Significant differences were found between the fertilizers as reflected on the number of pods per plant and total seed yield. Also, significant differences were observed in all other measured characters due to application of the nitrogen+ phosphorus +potassium fertilizers treatment in the two successive seasons. The nitrogen+ phosphorus potassium gave the best grain yield compared to all other fertilizer treatments. Nonetheless, carbohydrates%, starch%, protein% were increased when 21kg N/ha,43kg P_2O_5/ha and 45.22kg K_2O/ha dose, was applied. As well as the total flavonoids contents in faba bean (*Vicia faba* l.) was improved when 21kg N/ha ,43kg P_2O_5/ha and45.22kg K_2O dose was applied. Economic feasibility was tested using gross-rate (GR) analysis. The GR can be calculated by dividing gross profit by net sales. Economically, the results showed that the nitrogen+ phosphorus+ potassium dose gave the highest GR ratios (146%) compared to the other fertilizers, in the two successive seasons. Nitrogen+ phosphorus+ potassium is the best option for faba bean farmer in the River Nile State to be adopted for profitable yield.

Keywords: Chemical fertilizers, faba bean, gross rate of return, high Terrace

تحسين إنتاجية الفول المصري (*Vicia faba* L.) وجودة البذور باستخدام الأسمدة الكيماوية في تربة التروس العليا بولاية نهر النيل، السودان

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المستخلص

أجريت التجارب في مزرعة محطة أبحاث الحديبة في فصل الشتاء 18/2017 و19/2018. بغرض محاولة تحسين إنتاج الفول وجودة البذور باستخدام الأسمدة الكيماوية (النيتروجين والفوسفور والبوتاسيوم). حوت المعاملات ثمانية من تكوينات الأسمدة (نيتروجين، فسفور، بوتاسيوم، نيتروجين + فوسفور، نيتروجين + بوتاسيوم، بوتاسيوم + فوسفور ونيتروجين + فوسفور + بوتاسيوم وضبط، 21 كجم / N هكتار، 43 كجم / P_2O_5 هكتار و45.22 كجم / K_2O هكتار.). تم ترتيب المعاملات في تصميم القطاعات كاملة العشوائية (RCBD) بأربعة مكررات. وجدت فروق معنوية بين الأسمدة حيث انعكست على عدد القرون لكل نبات وإجمالي إنتاج البذور. كما لوحظت فروق معنوية في جميع الصفات المقاسة الأخرى تعزى إلى استخدام معاملة النيتروجين + الفوسفور + الأسمدة البوتاسية في الموسمين المتتاليين. كانت الفروق بين الأسمدة ذات دلالة إحصائية عالية في كل من حاصل البذور وعدد القرون للنبات. أعطى النيتروجين + الفوسفور + البوتاسيوم أفضل محصول حبوب مقارنة بجميع معاملات السماد الأخرى. ومع ذلك تمت زيادة النسبة المئوية للكربوهيدرات، النشا، البروتين عند تطبيق تلك الجرعة وكذلك تم تحسين محتوى الفلافونويد الكلي في الفول (Vicia faba L.) عند تطبيق جرعة 21 كجم نتروجين/هكتار، و43 كجم / P_2O_5 هكتار و45.22 كجم /K_2O هكتار. تم اختبار الجدوى الاقتصادية باستخدام تحليل العائد الإجمالي (GR) يمكن حساب GR بقسمة إجمالي الربح على صافي المبيعات. من الناحية الاقتصادية أظهرت النتائج أن جرعة النيتروجين + الفوسفور + البوتاسيوم أعطت أعلى نسب GR (146) ٪مقارنة بالأسمدة الأخرى في الموسمين المتتاليين. أثبتت النتائج ان النيتروجين + الفسفور + البوتاسيوم هو الخيار الأفضل لمزارع الفول المصرى في ولاية نهر النيل لاعتماده لتحقيق عائد مربح.

كلمات مفتاحية: الاسمدة الكيمائية، الفول المصري، معدل العائد الإجمالي، التروس العليا

Introduction

Faba bean (*Vicia faba* L.) is considered as one of the most favored winter-sown legume crop worldwide. It is an important crop with high protein and carbohydrates (Sepetoglu, 2002). Four main functions in the agro-ecosystems are provided by the crop: first giving food and feed rich in protein; second it increases soil fertility by symbiotic N_2 fixation; third if preceded, faba bean reduces constraints on growth and yield by the other crops in the rotation. In general, legumes are rich in nutritive value as animals feed as well as maintaining soil fertility and productivity (Mohammed and Elsheikh, 2014). Faba bean is considered as one of the most important cool-season food legumes produced in the River Nile State (RNS). The production is consumed

domestically. However, the often low production of the crop achieved by growers enforces researchers at Agricultural Research Corporation (ARC) to conduct more experiments to enhance both yield and quality. Considerable efforts were directed towards improving yield and protein content of faba bean through breeding, fertilization and improving cultural practices in Sudan. In improving agriculture production, low soil fertilizer is considered one of the major critical constraints (Ayoub, 1999). The regularly mono-cropping practices and crop intensification resulted in poor soil fertility that make application of fertilizers of must to enhance both faba bean production and quality in River Nile state.

The objectives of this research are to increase faba bean production using NPK fertilizers and the effect of them on carbohydrates, starch, protein, and flavonoids accumulation during faba bean seed development and maturation in RNS.

Materials and methods

This trial was conducted at Hudeiba Research Station Farm (17^0 34' N, 33^0 56' E 350 meters above sea level) located in the River Nile State. The local climate is semi-desert with an average annual rainfall of about 200 mm (Adam, 2005). The experimental site falls in high terrace series which is classified as Chromic Haplostorrts, Aridsol. Soil samples were taken from two depths (0-30 and 30-60 cm) from the site and analyzed for chemical and physical properties. Table (1) shows some physical and chemical properties of these High terrace soils. The soil is characterized by being low in Nitrogen, Phosphorous and organic Carbon, with calcareous, slightly sodic and clay matrix. The treatments consisted of eight fertilizers combinations (nitrogen, phosphorus, potassium, nitrogen+ phosphorus, nitrogen+ potassium, potassium+ phosphorus and nitrogen+ phosphorus potassium and control, 21kg N/ha, 43kg/P_2O_5/ha and 45.22kg K_2O/ha. Fertilizers form used were urea, triple super phosphate and potassium sulphate as sources of nitrogen, phosphorus and potassium. Two faba bean varieties were tested (Basabeer and Hudieba 93). The treatments were arranged in randomized complete block design (RCBD) with four replicates. As application and timing, the fertilizers phosphorus was added at sowing in furrow of the ridges. Nitrogen fertilizer was applied at sowing. While potassium fertilizer has been added in two phases of growing stages; first at sowing and second after one month from crop establishment. Faba bean varieties were directly planted on ridges 60 cm apart with intra-row spacing of 20 cm, and 2 seeds per hole. Plot size was (6×6m). In both seasons sowing was on 26th October and the irrigation was carried out every 7 days regularly. All other cultural practices were applied as recommended by (ARC), Sudan.

Crude protein (CP) content was determined by the Kjeldahl method (N ×factor of 6.25) using a Kjeltec Auto 1031 Analyzer (Foss Tecator, Sweden). For the determination of crude protein yield (CPY) the following expression was used:

$$CPY = CP \times SY/100 \ldots$$ (Barłóg *et al*., 2019).

The collected data included: plant height (cm), number of branches per plant, number of pods per plant, pods weight (g), 100 Seeds weight (g) and seed yield (ton/ha).

The gross rate of return on an investment is one measure of a project or investment's gross profit. It typically includes capital gains and any income received from the investment. Also gross rate is the rate of interest that you would earn at the beginning of taking out a savings account. It's useful as a rough guide. By comparison, the net rate of return deducts fees and expenses from the investment's final value. Once you determine gross profit, you can calculate the gross profit rate by dividing gross profit by net sales. The formula for gross rate of return is:

GR= (Final value – initial value)/ initial value

Results

Agronomic performance of faba bean (*Vicia faba* L.) was significantly affected by the treatments of chemical fertilizers over control. Tables (2 and 3) showed the effect of nitrogen+ phosphorus+ potassium on the grain yield and some other growth and yield components of two faba bean varieties (Basabeer and Hudeiba 93) in seasons 2017/18 and 2018/19. Results indicated significant effect of fertilization on all studied parameters. Fertilizer treatments, compared to control, increased plant height, number of branches per plant, number of pods per plant, pods weight, 100 Seeds weight and seed yield with the two varieties in both seasons. The highest seed yield was obtained by NPK (nitrogen+ phosphorus+ potassium) treatment with the two varieties in both seasons (3.9 for Basabeer and Hudeiba 93 in the first season and 4.2 and 3.6 ton/ha for Basabeer and Hudeiba 93 in the second season, respectively).

Results showed that the maximum plant height (cm), number of branches per plant, pods weight(g), 100 seeds weight(g) were also achieved when 21kg N/ha, 43kg P_2O5/ha and 45.22kg K_2O were applied in both seasons for the two faba bean varieties. Differences in results between seasons were attributed to that temperature in first season was lower than the second one.

Table 4 showed that the carbohydrates%, starch%, protein%, and total flavonoids were significantly increased by fertilizer treatment compared to the control ($p \leq 0.05$). The highest values were obtained by NPK treatment (55.11, 43.13, 28.04 and 6.01for carbohydrates%, starch%, protein%, and total flavonoids respectively).

Table (5) showed the gross profit rate for the different treatments applied. Fertilizer treatment 21kg N/ha ,43kg P_2O_5/ha and 45.22kgK_2O achieved gross rate of about146%.

Discussion

In All parameter fertilizer treatments over yield the control. Results also indicated best performance of the fertilizers treatment (nitrogen + phosphorus + potassium) over the other fertilizers treatments. Similar results were obtained by Mohammed and Elsheikh (2014) when they used chemical fertilizer in crop plant like carrot. Among nitrogen, phosphorus and potassium, the essential nutrients required by crop plants, nitrogen is the most commonly deficient in tropical soils. However symbiotic fixation is expected to compensate this deficiency in faba bean. High Terrace soils in Northern Sudan is mostly deficient in phosphorus so any addition of it is expected to increase yield. In an experiment on *Zea Mays* conducted by Al-Farhan and Al-Rawi (2002), they found that increasing phosphorus up to 80 kg/ ha increased

yield. Mona *et al*. (2011) also confirmed that among 0, 40 and 80kg/ ha phosphorus, 80kg/ ha produced the highest yield. Unlike others, Taha *et al.* (2016) found that the increase of plant available K in soil resulted in a lower tannin content, especially in mature seeds. To ensure a high yield of protein, the soil should be also characterized by a high content of available K. In soil with low or medium K content, Abou-Salama and Dawood (1994) found that increasing phosphorus up to 90 kg/ha could increase yield production. One of the most important reasons for non-significant effect of phosphorus on the yield of faba bean is its low efficiency in soil due to low solubility and sorption by calcareous and alkaline soils which is the typical case in the high terrace. In this study, faba bean crop gave high increase in seed yield and all yield components when the crop is fertilized with nitrogen + phosphorus + potassium fertilizers. Nonetheless, nitrogen+ phosphorus+ potassium gave the highest significant influences compared with other treatments. These differences appeared on the number of pods per plant, 100 seed weight ($P \leq 0.05$) and the total grain yield ($P \leq 0.05$). Likewise, Mani (2002) cited that increase in NPK led to a significant increase in plant height and grain yield. Barłóg *et al*. (2014) and Barłóg *et al.* (2019) stated that K fertilization causes slim increase in Lys and Cys amino acids in faba bean seeds. Results of carbohydrates%, starch%, protein%, and total flavonoids were influenced by fertilizer sources ($p \leq 0.05$). Crude protein (CP) as a nitrogen molecule is expected to increase with increasing nitrogen fertilizer treatments. Also, crude protein increased on applying P and K treatments, and interaction between these fertilizers. It is obviously observed that the rates of carbohydrates, starch, protein were increased when NPK dose was applied. Further, the total flavonoids contents in faba bean (*Vicia faba* l.) were increased when 21kg N/ha ,43kg P_2O_5/ha and 45.22kg K2O dose was applied.

Conclusion

Based on the results of this study the followings can be concluded; the addition of 1N (21Nkg/ha) + 1P (43 P_2O_5kg/ha) + K_2O (45.22 K_2Okg/ha) showed significant effects on faba bean yield in high terrace soils. The potassium sulphate, nitrogen and phosphorus gave the best seed yield, and seeds quality. The nitrogen phosphorus potassium realized the best economic feasibility (GR%= 146%) for growing faba bean in the River Nile State, Sudan.

Table (1): Soil properties of four analyzed auger samples of the experimental site (High terrace).

EC_e	SAR	ESP	O.C%	$CaCO_3$%	K Meg/l	P PPm	N PPm	Sand%	Clay%	Silt%
2.5	10.0	11.0	0.106	9.0	2.210	1.9	140	61	36	3
1.7	9.0	9.6	0.102	8.0	1.316	2.0	220	58	40	2
2.5	11.0	12.1	0.123	8.0	2.014	2.0	231	62	35	3
2.3	9.0	11.2	0.305	7.0	2.O26	2.1	224	56	40	4

Source Hudeiba soil lab Station, EC_e= Electrical Conductivity of Saturation Extract.
O.C = Organic Carbon, SAR=Sodium Adsorption Ratio, ESP=Exchange Sodium percentage.

Table (2): Effect of chemical fertilizers on plant height, number of branches per plant, pod weight, 100 seeds weight and yield (ton/ha) of faba bean during seasons 2017/18 at Hudeiba Research Station Farm.

Treat meant	Plant height (cm)	No. of branches/plant	Pod weight (g)	100Seeds weight (g)	Yield (ton/ha)
Basabeer					
21kghaN	100	5	8.12	59	2.6
K_2O	100	5	7.54	61	2.6
P_2O_5	103	6	7.91	60	2.7
$N+K_2O_5$	111.60	7	9.14	64	3.0
$N+P2O_5$	114	8	11.52	69	3.1
$P_2O_5+ K_2O$	126.8	7	12.1	63	3.0
$N+P_2O_{5+}K_{2O5}$	126.8	9	13.91	74	3.9
Control	85.6	4	7.00	56	0.7
Mean	106.1	6.4	9.4	55.2	2.8
L.S.D	3.65	1.0	1.87	4.9	.21
C.V %	10.8	3.00	5.4	15.5	.63
Hudieba 93					
N	109	5	7	61	2.7
K_2O	108	6	7	64	2.8
P_2O_5	100	6	8	64	2.8
$N+K_2O$	115	7	8	65	3.0
$N+P_2O_5$	120	7	9	67	3.1
$K_2O+ P_2O_5$	123	8	12	60	3.0
$N+ P_2O_5 +k_2O$	130	9	14	71	3.9
Control	100	4	6	52	0.6
Mean	115	6.7	8	63.1	3.2
L.S.D	1.54	1.9	1.0	2.1	0.83
C.V %	5.51	5.76	3.0	6.3	2.6

Significantly differences at $P \leq 0.05$ level.

Table (3): Effect of chemical fertilizers on plant height, number of branches per plant, pod weight, 100 seeds weight and yield (ton/ha) of faba bean during seasons 2018/19 at Hudeiba Research Station Farm

Treat meant	Plant height(cm)	No. of branches/plant	Pod weight (g)	100 Seeds weight (g)	Yield (ton/ha)
Basabeer					
21kg/haN	99.12	4.97	7.10	56	2.1
K_2O	100	4.80	8	64	2.2
P_2O_5	101	5.90	8.10	62	2.8
$N+K_2O_5$	109	6.99	9.21	63	3.3
$N+P2O_5$	114	8.40	12	71	3.1
$P_2O_5+ K_2O$	124	7.54	13	65	3.1
$N+P_2O_5+K_{2O}$	123	9.45	12.90	77	4.2
Control	86.10	4.21	6.99	54	.83
Men	107	6.4	9.7	64	2.7
L.S.D	2.8	.67	1.34	3.1	.25
C.V	11	3.9	6.1	11	.73
Hudieba93					
N	111	5	6.6	67	2.9
K_2O	112	6	6.8	69	2.6
P_2O_5	102	6	8.3	68	2.5
$N+K_2O$	113	7	8.4	68	3.4
$N+P_2O_5$	118	7	9.4	69	3.2
$K_2O+ P_2O_5$	1120	8	12.40	64	3.3
$N+ P_2O_5 +k_2O$	127	9	14.50	75	3.6
Control	101	4	6.45	49	.71
Mean	112	6.6	6.5	65	2.8
L.S.D	.33	1.9	.90	2.2	0.89
C.V %	6.4	5.76	6.7	4.2	2.8

Significantly differences at $P < 0.05$ level.

Table (4): Effect of chemical fertilizers treatments and varieties of faba bean seeds season 2017/18 and 2018/19

Treatment	Carbohydrates %	Starch%	Protein %	Total flavonoids (mg/g)
Basabeer				
21kgN/ha	45.53	34.21	21.10	2.88
45.22kgK_2O/ha	49.14	34.44	22.76	3.0
43kgP_2O_5/ha	50.12	35.11	23.12	4.19
21kgN/ha+ 45.22kgK_2O/ha	51.17	35.32	24.41	4.99
21kgN/ha+ 43kgP_2O_5/ha	52.10	38.15	24.78	5.06
43kgP_2O_5/ha+ 45.22kgK_2O/ha	51.11	35	24	5.93
21kgN/ha+ 43kgP_2O_5/ha + 45.22kgK_2O/ha	55.11	43.13	28.04	6.01
Control	42.17	30.19	19.19	1.53
LSD	0.07	0.15	0.05	0.06
Hudieba 93				
21kgN/ha	48.17	31.	21.10	2.85
45.22kgK_2O/ha	50.23	32.13	22.76	2.97
43kgP_2O_5/ha	51.12	33.77	23.12	4.15
21kgN/ha+ 45.22kgK_2O/ha	51.51	33.97	24.41	4.65
21kgN/ha+ 43kgP_2O_5/ha	52.65	35.76	24.78	4.78
43kgP_2O_5/ha+ 45.22kgK_2O/ha	52	34	24.1	4.1
21kgN/ha+ 43kgP_2O_5/ha + 45.22kgK_2O/ha	57.13	39.89	28.04	5.55
Control	44.1	28.90	19.19	1.34
LSD	0.05	0..18	0.05	0.06

Source: food research center

Table (5): Faba bean combined cost items and the gross rate for one hectare using different fertilizers in seasons 2018/19 and 2019/20

Fertilizers	Total produce MT/ ha.	Net sales SDG / ha.	Total cost SDG / ha.	Gross profit SDG / ha.	Gross profit rate	GR %
21kgN/ha	2.6	312000	127330	184670	1.450326	145
45.22kgK_2O/ha	2.6	312000	138040	173960	1.260214	126
43kgP_2O_5/ha	2.7	324000	142800	181200	1.268908	127
21kgN/ha+ 45.22kgK_2O/ha	3.0	360000	146370	213630	1.45952	146
21kgN/ha+ 43kgP_2O_5/ha	3.1	372000	151130	220870	1.461457	146
43kgP_2O_5/ha+ 45.22kgK_2O/ha	3.0	360000	161840	198160	1.224419	122
21kgN/ha+ 43kgP_2O_5/ha+ 45.22kgK2O/ha	3.9	448000	170170	277830	1.632661	163
Control	0.7	84000	119000	-35000	-0.29412	-29.4

Source: Authors calculation

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