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Effects of Irrigation, Rhizobium Inoculant and Rock Phosphate on Some Pod Characteristics of Snap Beans Grown during Short Rainy Season in Northern Tanzania

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Abstract: A screen house experiment was performed to evaluate the effect of irrigation, rhizobium inoculant and rock phosphate on some pod characteristics of snap beans (*Phaseolus vulgaris* L) during short rainy season in Northern Tanzania. The experiment was laid out in a 4 x 2 factorial in randomized complete block design (RCBD). The four factors were irrigation (0%, 25%, 50% and 75%) and the two factors were Fertilizer combination (rhizobium and rock phosphate) and check or control (without rhizobium inoculant and rock phosphate). The results showed that snap beans that were not irrigated produced no pod yield. The highest irrigation level produced the highest number of pods and highest pod weight. The plants raised on soil medium with the rhizobium and rock phosphate fertilizer produced significantly ($p<0.05$) higher number of pods per plant than the check soil medium. Fertilization did not make a significant difference on the pod width and pod length of snap beans.

Key words: Irrigation · Rhizobium Inoculation · Rock Phosphate · Snap Bean Pod Quality

INTRODUCTION

Snap bean (Also called ‘French bean’) is a cultivar of common bean, *Phaseolus vulgaris* L, grown for its green pods. It is the most important high value bean grown in East and Central Africa [1]. It is a fairly popular vegetable crop in East Africa, where it is cultivated as a source of protein and a cash crop by small and medium scale farmers. Snap bean is a crucial source of income for smallholder farmers in Kenya, Tanzania, Uganda and Sudan [2]. In that region, more than 90% of the crop produced is exported to regional and international markets [3].

Snap beans have a high market value, mature much earlier and have longer harvest duration [4]. They are rich in vitamins, minerals and dietary fiber [5]. Specifically, snap beans are nutritionally rich in vitamin A, vitamin C, iron and calcium which can contribute significantly to mixed diets.

Pod yield and pod quality are very vital in snap bean production. Pod yield determines the profitability of the enterprise and pod quality decides the competitiveness of the produce in local and international markets. While pod quality preferences in snap beans vary from region to region, characteristics such as pod length, straightness, smoothness and rate of seed development, among others, are the key determinants of the acceptability of snap beans by consumers and processors [6, 7].

Most markets prefer uniform, fresh, clean, insect and disease-free pods. Production of snap bean with quality characteristics conforming to the market taste is crucial to increasing consumption [8]. European Union markets have strict safety and quality standards which African farmers and this is increasingly limiting export opportunities available to African farmers [9].

Furthermore, one of the main constraints to snap bean production in Tanzania is the challenge of low soil fertility [9]. Farmers apply inorganic fertilizers to improve

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the nutrition status of the soil in order to secure reasonable yield. However, fertilizer prices have risen by 500% since 2000, while market prices of snap beans have only increased by 50% and therefore, forcing snap bean growers to operate on increasingly thinner profit margins. This situation makes the efficient use of P imperative to achieve long-term profitability [10].

Pod quality of snap bean can be affected by cultural practices including N and P fertilizers [11, 12]. Tanzanian snap farmers are increasingly embracing the use of rhizobium and rock phosphate as alternative fertilizers. Application of rhizobia and rock phosphate (rock P) is agronomically more useful and environmentally safer than soluble P and N [13]. The use of natural elements compounds improves the soil physical and chemical properties as well as water uptake and nutrient availability [14].

It is estimated that about 60% of the bean growing area in the tropics is affected by terminal or intermittent drought stress [15]. Evidence suggests that snap beans farming in East Africa is becoming increasingly threatened by climate change and weather variability, in spite of the growing export market demand [16]. Average bean yields in Tanzania are around 500 kg/ha although the potential yield under reliable rainfed conditions is 1500–3000 kg/ha, using improved varieties.

Beans do not tolerate prolonged dry spell. Therefore, supplementary irrigation is required to obtain reasonable yield in the drier areas. Thus, the main areas of beans production are the mid to high altitude areas of the country, which experience more reliable rainfall and cooler temperatures. The most suitable areas for bean cultivation in Tanzania are in the northern zone, particularly Arusha Region, the Great Lakes region in the west and in the Southern Highlands.

The objective of the present study was to evaluate the effect of rhizobium and rock phosphate fertilizer combination and water stress on the pod characteristics of snap beans in Tanzania.

MATERIALS AND METHODS

Experimental Site: Field experiment was conducted at Uyole Agricultural Research Institute (ARI), Mbeya, Tanzania during the short rainy season (December 2017 to February 2018). Uyole is located at latitude 08°53’ S, longitude33°3’E and altitude 1, 778 meters above sea level. Soil sample were collected at 0-20 cm depth from snap beans growing site in Meru Council, Maweni village and transported to the screen house. Soil sample analysis was done to determine the physical and chemical properties of soil at ARI, Uyole. The results are shown in Table 1.

Experimental Design: The experiment was laid out in a 4 x 2 factorial in a randomized complete block design (RCBD) with three replications. The experiment comprised two factors, namely irrigation levels (0%, 25%, 50% and 75%) and fertilizer combination (Rhizobia and Minjingu rock phosphate). The rhizobium used is BIOFIX for legume seeds, tropici strain CIAT 899 (University of Nairobi, MEA-2017). The rock phosphate is an organic hyper phosphate fertilizer with 29-30% P_20_5 and 38-40% CaO.

Irrigation was done every 5-7 days from the date of planting. For soil water content maintenance, a measured container was used to replace water calculated from water field capacity (F.C) by the gravimetric method [17, 18]. Fertilization with rock phosphate (Minjingu rock phosphate) was done at the rate of 1g/kg of soil before potting [19]. Snap bean seeds were inoculated with rhizobium before planting. Data were collected on plant height, number of pods per plant, weight of pods per plant, pod width and pod length. They were subjected to analysis of variance and means were separated at 5% probability level using Genstat software.

RESULTS

Snap beans grown without irrigation were significantly ($p<0.05$) shorter than other plants that received various levels of irrigation. The three irrigation treatments produced statistically similar plants with respect to plant height. IL_2 irrigation gave the tallest snap bean plants. The medium without fertilizer and the media treated with rhizobium and rock phosphate produced statistically similar plant heights. The highest interaction effect of irrigation and rhizobium and rock phosphate combination on plant height was observed on snap beans raised on pots treated with IL_2 and the fertilizer combination and this was significantly ($p<0.05$) different from the lowest interaction effect which was observed on plants grown without irrigation and fertilizer.

On number of pods per plant, the check treatment of no irrigation gave zero yield. The plants raised on soil medium with the rhizobium and rock phosphate fertilizer produced significantly ($p<0.05$) higher number of pods per plant than the check soil medium. Plants given the highest level of irrigation produced the highest number of pods

Table 1: Soil sample characteristics

Parameter	Unit	Results
Soil ($_P$H.$H_2$0)		7.4
Texture	Sandy (%)	42.8
	Silt (%)	20
	Clay (%)	37.2
Total Nitrogen (N)	%	0.067
Organic Carbon (C)	%	3.34
Available phosphorus (P)	mg/kg	11.4
Moisture factor	%	8.23
Water field capacity	%	85.51
Cation Exchangable Capacity (CEC)	*me*/100g	34.16
EC	*Ms/cm*	0.47
Exchangeable base (Na^+)	Cmol/kg	0.02
Potasium (K^+)	Cmol/kg	0.97
Magnesium (mg)	Cmol/kg	4.66
Calcium (Ca)	Cmol/kg	22.6
Zinc (Zn)	Ppm	1.04
Manganese (Mn)	Ppm	1.6
Iron (Fe)	Ppm	0.37

Table 2: Effect of irrigation and rhizobium and rock phosphate combination on plant height, number of pods per plant and pod weight of snap beans

Fertilizer combination	Irrigation level				Mean
	Plant height (cm)				
	IL_O	IL_I	IL_2	IL_3	
F_0	32	54	52.7	45	45.9
F_1	33	52.7	65.3	62.3	53.3
Mean	32.5	53.3	59	53.7	
	Number of pods per plant				
F_0	0	4	4.67	5.67	3.58
F_1	0	4.67	6.67	6.67	4.5
Mean	0	4.33	5.67	6.17	
	Pod weight (g)				
F_0	0	1.513	2.03	1.91	1.363
F_1	0	1.617	2.32	2.453	1.598
Mean	0	1.565	2.175	2.182	

	Plant height	Number of pods	Pod weight
$LSD_{0.05}$ for fertilizer	7.99	0.661	0.262
$LSD_{0.05}$ for irrigation	11.3	0.935	0.2196
$LSD_{0.05}$ for fert. x irrigation	15.97	1.322	0.4124

F_0= no fertilizer combination; F_1= rhizobium inoculant and rock phosphate; IL_O= no irrigation; IL_I=25% irrigation level; IL_2=50% irrigation level; IL3 =75% irrigation level

Table 3: Effect of irrigation and rhizobium and rock phosphate combination on pod width and pod length of snap beans

Fertilizer combination	Irrigation level				Mean
	IL_O	IL_I	IL_2	IL_3	
	Pod width (cm)				
F_0	0	0.6	0.6267	0.6233	0.4625
F_1	0	0.5967	0.63	0.63	0.4642
Mean	0	0.5983	0.6283	0.6267	
	Pod length (cm)				
F_0	0	10.45	11.703	11.797	8.487
F_1	0	10.497	11.957	11.823	8.569
Mean	0	10.473	11.83	11.81	

	Pod width	Pod length
$LSD_{0.05}$ for fertilizer	0.01758	0.3466
$LSD_{0.05}$ for irrigation	0.02486	0.4902
$LSD_{0.05}$ for fertilizer x irrigation	0.03515	0.6932

F_0= no fertilizer combination; F_1= rhizobium inoculant and rock phosphate; IL_O= no irrigation; IL_I=25% irrigation level; IL_2=50% irrigation level; IL3 =75% irrigation level per plant and this was statistically different from the pod yields of the check and IL_1 but statistically similar to that of IL_2. The highest interaction effect of irrigation and rhizobium and rock phosphate combination on number of pods per plant was observed on snap beans grown on soil medium with fertilization combination and irrigation rates IL_2 and IL_3 rates.

The check soil medium and the soil medium with rhizobium and rock phosphate produced plants with statistically similar pod weights. The pod weight of snap beans grown on soil medium irrigated with IL_2 was higher than the pod weight of soil medium irrigated with IL_1. The pod weights of plants treated with irrigation rates of IL_2 and IL_3 were statistically similar. The highest interaction effect of irrigation and rhizobium and rock phosphate combination on pod weight was observed on snap beans grown on soil medium treated with the highest irrigation level of IL_3 and rhizobium and rock phosphate combination and this is significantly ($p<0.05$) different from the lowest interaction effect which was observed on plants grown on soil medium without irrigation and the fertilizer.

There was no significant difference between the pod width of snap beans grown with soil treated with the fertilizer and that of the check medium. The soil medium irrigated with IL_2 rate produced the highest pod width figure and this was significantly ($p<0.05$) higher than the pod width value of soil medium irrigated with IL_1 but statistically similar to that of the highest irrigation level. The highest interaction effect of irrigation and rhizobium and rock phosphate combination on pod width was observed on snap beans grown without fertilizer and irrigated with IL_2.

The pod length of snap beans grown without fertilizer was statistically similar to that of the plants raised with the fertilizer combination. Plants grown with irrigation rate IL_2 had the longest pods and their pod length is significantly ($p<0.05$) higher than that of plants raised with IL_1 and relatively higher than the pod length of plants given the highest irrigation rate of IL_3. The highest interaction effect of irrigation and rhizobium and rock phosphate combination on pod length was observed on plants irrigated with irrigation level IL_2 and raised with the fertilizer combination while the lowest interaction effect of irrigation and rhizobium and rock phosphate combination on pod length was observed on snap beans grown without fertilizer and irrigated with the rate IL_2.

DISCUSSION

Snap beans that were not irrigated produced no pod yield. They died before completing their growth cycle. This indicates that water stress is a decisive limiting factor in snap beans production and that in cases of extreme draught, crop failure will result. Thus, irrigation is necessary to achieve reasonable crop yield in areas with highly variable and/or inadequate rainfall [20].

Unmitigated drought is one of the main causes of yield loss in agriculture. A meta-analysis of available literature data on controlled experiments which compared irrigated conditions and irrigation reduction showed that irrigation water reduction reduced yield in maize by 39% and in wheat by 20% [21].

The highest irrigation level produced the highest number of pods and highest pod weight. This suggests that the water needs of snap beans must be met for profitable yield to be achieved. This finding is consistent with the report that the volume of irrigation water influences green bean productivity [22]. It has been reported that higher irrigation levels led to a significant increase in the number of pods of common bean [23].

The high number of pods and pod weight of snap beans treated with rhizobium inoculant and grown with rock phosphate relative to plants grown without fertilizer shows that N and P fertilization is crucial to pod yield. It has been reported that rhizobium inoculation is effective in improving marketable yield of snap bean pods. Plants inoculated with rhizobium have been reported to have increased levels of dry matter, nitrogen and phosphorous content [25, 26]. Many researchers have also observed the beneficial effects of applying natural rocks on green pod yield of beans. The positive influence of rock phosphate application has been observed on common bean [28-30]; on mung bean [31]; on peas [32]; and on wheat, chick pea and cluster bean [33]. They reported that the application of Minjingu rock phosphate increases yield of beans. An investigation of the impact of seed, nitrogen and phosphorus on the total production of the main crops produced in Egypt under irrigated conditions showed increasing returns of scale for wheat, rice and maize production [34].

Fertilization did not have a significant difference on the pod width and pod length of snap beans. This could be attributed to the fact that pod shape traits are genetically fixed and so may not be amenable to significant phenotypic variation arising application of production input. This brings home the imperative of selecting snap bean cultivars with marketable pod quality for use in commercial production.

CONCLUSION

The simulation of extreme draught scenario proved that unmitigated water stress can result in total crop failure. This makes clear that climate change currently being observed in the snap bean growing areas of Tanzania calls for a dependable irrigation strategy. The results also indicate that there exists a promising case for the use of rhizobium inoculant and rock phosphate as alternative source of N and P for resource poor farmers engaged in snap bean production.

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