INFLUENCE OF SOIL MOISTURE CONTENT AND FERTILIZER POTASSIUM ON THE GROWTH OF COWPEA (Vigna unguiculata) IN SANDY REGOSOL

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ABSTRACT: *Cowpea is grown in a wide range of environments, and drought is considered as the single most devastating environmental stress, which decreases crop productivity more than any other environmental stress. Lack of adequate soil moisture affects both the vegetative and reproductive growth of legumes and leads to significant yield loss. Potassium fertilizer mitigates the impact of water stress in plants. A study was conducted from July to September 2018 to investigate the effect of four rates of fertilizer potassium (MOP) including recommended level (75Kg/ha), 125% of recommended level, 150% of recommended level, 175% of recommended level with two different soil moisture conditions as optimal and sub-optimal on growth of cowpea. These 8 treatments replicated three times in a Completely Randomized Design (CRD) in a factorial manner. Growth parameters of cowpea were recorded. The data were statistically analyzed using SAS and difference between treatment means was compared using Duncan's Multiple Range Test (DMRT). The tap root length of cowpea showed a greater response to potassium fertilizer under suboptimal soil moisture. Although differences were observed in the responses of the vegetative growth of cowpea to moisture and potassium, in overall terms potassium promoted growth of cowpea when subject to suboptimal soil moisture. Among all applications 175% of recommended potassium level of cowpea proved to be the best to increase the shoot dry weight and leaf area at optimal moisture conditions, and under sub-optimal moisture conditions it was the best to increase the shoot dry weight and leaf area compared to recommended level of potassium in sandy regosol soil. The results of this study suggested that the application of potassium fertilizer can be considered as significant factor in overcoming soil moisture stress in cowpea.*

Keywords: Cowpea, Drought, Moisture Stress, Potassium.

1. INTRODUCTION

World population is growing at a higher rate and its greatest impacts are on the developing countries of Asia and Africa. Sri Lanka is a South Asian developing country mainly depends on agriculture for the economic growth, and affected by this population impact. Due to this, food security has become a major issue in Sri Lanka. So, enhancing the crop productivity to ensure food security is more important to provide better nutrition to our people and to increase their standard of living.

Water is becoming a scarce commodity for irrigation especially under the present changing climatic scenario. Scarcity of water for agriculture has a negative impact on the crop production. Drought is the most severe abiotic stress which affects the growth and yield of various crops. Improving the mineral nutrient status of plants under drought is important to maintain the crop productivity.

Cowpea is an important legume crop widely cultivated in Sri Lanka. It is an inexpensive and rich source of protein. Cowpea is often subjected to drought stress in both seedling and terminal growth stages which cause a considerable amount of loss in biomass production (Amos Afolarin Olajide and Christopher Olumuyiwa Ilori, 2017).

Among the plant nutrients, potassium (K) is one of the major nutrient essential for the plant growth and physiology. Potassium decreases different stress effects in plants such as drought, chilling and high light intensity. Under drought stress condition potassium regulates the stomatal opening and makes the plants adaptive to water deficit (Mirza Hasanuzzaman *et al*., 2018). So, drought stress cultivars combined with adequate external potassium supply may be a good strategy to increase the crop growth and productivity in arid and semi-arid regions.

The predominant soil group in Batticaloa district and the coastal belt of Eastern province, Sri Lanka is sandy regosol (Quartzipsamments) which contain 95-98% sand with no confining horizons in its soil profile (Bawatharani *et al*., 2004). Sandy regosol soil is light and easy to work. Also the cultivation can be carried out all year round and it favours better air and water movement and root penetration.

Though the effects of water stress on cowpea production have been studied, a little is known about the effects of water stress on growth components. A better understanding of the effects of water stress on cowpea growth and physiology will provide useful information to farmers on how to manage the cowpea production under drought conditions, and also a few studies have demonstrated that the use of potassium fertilizer can reduce the adverse effects of water stress in cowpeas in controlled environmental conditions (Fooladivanda *et al*., 2014). Fertilizer potassium would be expected to have some effects on cowpea in overcoming moisture stress. Though there are ample amount of research findings on the impact of potassium on the growth of cowpea under moisture stress there is no such amount of data for the crop grown under exposed environmental conditions. Therefore to, investigate this possibility; an experiment was carried out under exposed environmental conditions in the sandy regosols of Batticaloa district to determine the impact of fertilizer potassium on the growth and development of cowpea under two different soil moisture conditions and to select the best combination of potassium level and soil moisture condition for the optimum growth and yield of cowpea.

2. METHODOLOGY

2.1 Description of Experimental Site

The experiment was conducted during the Yala season of the year 2018 at the Eastern University, Sri Lanka which is situated in the Batticaloa district, Sri Lanka. The elevation of this area is 75m above mean sea level and it is classified under the agro-ecological zone of the low country dry zone. The mean annual rainfall of Batticaloa district varies from 1800mm to 2100 mm and most of the showers are received during the months of October to January (Maha season) brought about by the North East monsoon. The annual mean temperature varies from 28 to 32^{0}c and humidity ranges from 60% to 90%.

2.2 Description of the Experiment and Growth Conditions

A pot experiment was carried out from July to September, 2018 in a wire house with rainproof roof, in order to avoid interruption by rainfall. The indoor environment of the wire house was kept similar to the outdoor environment.

a. *Soil Sample*

The soil was collected from the surface layer (0-15 cm) of the Agronomy farm, Eastern University, Sri Lanka. The soil used in this study was sandy regosol.

b. *Collection of Seeds*

Cowpea seeds of Wijaya variety were used for this experiment and seeds were collected from the seed unit of Agronomy farm, Eastern University, Sri Lanka.

2.3 Experimental Design and Preparation of Treatments

a. *Experimental Design*

The experiment was conducted in a factorial complete randomized design with eight treatments (4 potassium levels and 2 soil moisture conditions) and three replicates. A total number of 24 bags were used for this experiment.

b. *Treatments*

Soil's field capacity (52%) was measured in volume basis by adding 100ml water for 100ml soil. Depletion of available soil moisture at 25% and 75% were determined in volume basis and defined as optimal moisture condition and sub-optimal moisture condition, respectively. Soil moisture was monitored at every two days interval by weighing the bags. According to the Department of Agriculture recommendation the optimum potassium level for cowpea is 75kg/ha. For this experiment 25%, 50% and 75% increase of recommended potassium levels were used and they were defined as 125%, 150% and 175% potassium level, respectively.

c. *Treatment Structure*

F1K1 Sub-optimal moisture condition+potassium at 125% of recommendation

F1K2 Sub-optimal moisture condition+potassium at 150% of recommendation

F1K3 Sub-optimal moisture condition+potassium at 175% of recommendation

F1K0 Sub-optimal moisture condition+potassium at recommendation (control)

F2K1 Optimal moisture condition+potassium at 125% of recommendation

F2K2 Optimal moisture condition+potassium at 150% of recommendation

F2K3 Optimal moisture condition+potassium at 175% of recommendation

F2K0 Optimal moisture condition+potassium at recommendation (control)

According to the recommended rate, treatments were applied to the bag three days before planting.

d. *Pot Culture Experiment*

Black polythene bags were used for this experiment with the dimension of 36cm in diameter and 40cm in height. A bulk soil sample was collected was processed, air dried and sieved by using 2mm mesh sieve, for homogeneity. Each polythene bag was filled with seven (7) Kg of processed soil. Then they were properly labeled and arranged according to the design.

Nitrogen and phosphorus fertilizers were incorporated with the soil as per the recommendation and potassium was incorporated according to the treatments.

4 pre-treated seeds were sown in each bag and two weeks after germination, two plants per bag were maintained.

All the agronomic practices were applied according to the recommendation of Department of Agriculture, Sri Lanka.

2.4 Measurements

Growth parameters were measured to evaluate the growth performances of cowpea in each treatment at vegetative (30 days after planting) and harvesting stages (60 days after planting).

- Tap root length (cm).
- Dry weight of shoot (g).
- Leaf area (cm^2).

2.5 Statistical Analysis

All the data were analyzed using Analysis Of Variance (ANOVA) procedure to know the variance if any at the treatment level. Duncan's Multiple Range Test (DMRT) was used to compare the significant differences between treatment means at $p < 0.05$ using SAS 9.1.3 statistical software package.

3. DISCUSSION AND RESULTS

3.1 Length of tap root

Table 1. Effect of Soil Moisture Content and Potassium Rates on the Length of Tap Root of Cowpea Plant (cm).

Growth stage	Rate of MOP	Moisture condition	
		Sub-optimal	**Optimal**
Vegetative	**125%**	9.900 ± 0.378[b]	7.433 ± 0.120[c]
	150%	10.166 ± 0.638[b]	8.266 ± 0.144[b]
	175%	12.166 ± 0.202[a]	10.266 ± 0.144[a]
	Recommendation	8.266 ± 0.392[c]	6.333 ± 0.333[d]
	Moisture content	$P < 0.05$	
	MOP	$P < 0.05$	
	Interaction	$P > 0.05$	
Harvesting	**125%**	12.666 ± 0.088[c]	13.533 ± 0.120[b]
	150%	15.233 ± 0.120[a]	13.500 ± 0.288[b]
	175%	17.366 ± 0.185[a]	15.533 ± 0.240[a]
	Recommendation	12.633 ± 0.185[c]	13.733 ± 0.176[b]
	Moisture content	$P < 0.05$	
	MOP	$P < 0.05$	
	Interaction	$P < 0.05$	

The values are means of replicates ± standard error

Means with the same letter(s) are not significantly different from each other according to the Duncan multiple range test at 5% significant level.

The results pertaining to the length of tap root of cowpea plant indicated that there was a significant influence of soil moisture on the length of tap root of cowpea in both vegetative and harvesting stages (Table 1) as P value is less than 0.05.

Among the treatments highest value was received under sub-optimal moisture condition at vegetative (12.166cm) and harvesting stages (17.366cm). It may be due to lack of soil water in the shallow layers of soil under sub-optimal conditions; plants extended their roots in order to absorb water from the deeper layers of soil. This was supported by Sangakkara *et al*. (2001) and he stated that, the growth of roots was more extensive under the lower soil moisture regime and this is a response of plants to low soil moisture. Lowest values were observed in the optimal soil moisture condition compared to sub-optimal condition especially, in the vegetative stage. Because, there may be enough water in the root zone and no need to search for water in the deeper layers of soil. Sangakkara *et al*. (2001) also stated that, increasing soil moisture reduced the mean length of roots in cowpea.

The results (Table 1) revealed that, there was significant influence by the rate of potassium on the root length of cowpea plant as P value is less than 0.05 in both growth stages.

Increasing levels of potassium increased the tap root length at vegetative stage and significantly highest length was observed at 175% potassium level under sub-optimal condition. This may be due to the impact of potassium on the tap root length of cowpea. Ahmad *et al*. (2016) found that potassium application increased the root length under water stressed environment. A significant reduction of tap root length was observed at recommended level of potassium under sub-optimal condition. Because, decreasing level of soil moisture decreases the potassium availability due to the decreasing mobility of potassium under low water conditions. Under optimal moisture increasing level of potassium significantly increased the tap root length. This was because of the increased mobility of potassium and increased availability of potassium under high moisture content as the water moves passively to and across the roots at a high rate (Steudle, 2000).

At harvest, among the treatments impact of potassium at the rates of 150% and 175% was significantly high under sub-optimal soil moisture condition. This suggests that potassium promoted root growth in cowpea to a greater extent. In addition to that under optimal moisture condition recommended and 125% potassium levels produced longer tap roots compared to sub-optimal condition. Under low moisture conditions rate of potassium inflow is low. It may cause the reduction in root length. Similar results were observed by Kuchenbuch *et al*. (1986). At harvest recommended and 125% potassium levels under sub-optimal moisture produced significantly smaller roots compared to optimal moisture at the same rates of potassium. This may be due to the fact that prolonged drought decreases the potassium concentration, so the potassium concentration may be not enough to produce larger roots. This was supported by McWilliams (2003).

At harvest interaction between moisture condition and potassium rates shows significant influence as *P* value is lesser than 0.05 (Table 1).

Compared to optimal moisture conditions significantly longer tap roots were produced at 150%, 175% potassium under sub-optimal moisture. This shows that increasing levels of potassium has a greater influence under dry conditions than under optimal conditions in cowpea. It means the root system of cowpea responds to potassium under soil moisture stress. Wang *et al*. (2013) stated that the impact of potassium was greater in suboptimal soil moisture condition in cowpea and soil moisture influences the uptake rate of potassium via affecting its mobility from the soil to the root surface. Better root growth increased the nutrient uptake ability of root and led to good nutrient supply to plants. Onuh and Donald (2009) supported the fact that plants growing under water stressed conditions tend to elongate their roots around the growth environment in an attempt to capture water and absorb water from the rhisosphere. Camposeo and Rubino (2003) observed that under drought conditions cowpea roots increase the capacity of absorbing water only of the deeper younger roots.

3.2 Shoot dry weight

The results pertaining to the effect of potassium application on shoot dry weight of cowpea was significantly influenced by soil moisture content with potassium as *P* value is less than 0.05.

Table 2. Effect of Soil Moisture Content and Potassium Rates on the Shoot Dry Weight of Cowpea Plant (g).

Growth stage	Rate of MOP	Moisture condition	
		Sub-optimal	Optimal
Vegetative	**125%**	0.853 ± 0.049[b]	0.956 ± 0.206[bc]
	150%	0.750 ± 0.174[b]	1.326 ± 0.193[ab]
	175%	1.383 ± 0.046[a]	1.503 ± 0.577[a]
	Recommendation	0.440 ± 0.185[b]	0.690 ± 0.046[c]
	Moisture content	$P < 0.05$	
	MOP	$P < 0.05$	
	Interaction	$P > 0.05$	
Harvesting	**125%**	2.419 ± 0.020[c]	4.074 ± 0.072[a]
	150%	2.744 ± 0.047[b]	4.215 ± 0.044[b]
	175%	3.214 ± 0.053[a]	6.748 ± 0.032[a]
	Recommendation	1.850 ± 0.050[d]	3.617 ± 0.031[c]
	Moisture content	$P < 0.05$	
	MOP	$P < 0.05$	
	Interaction	$P < 0.05$	

The values are means of replicates ± standard error

Means with the same letter(s) are not significantly different from each other according to the Duncan multiple range test at 5% significant level.

Results obtained revealed that there was significant influence of soil moisture on shoot dry weight of cowpea plants as P value is less than 0.05 (Table 2).

Shoot dry weight was greater under optimal moisture condition than the sub-optimal condition at both vegetative and harvesting stage. Lower shoot dry weight under sub-optimal moisture was may be due to the low production of total dry mass under water stress. These findings are in support of previous findings of Felício Lopo de Sá *et al*. (2014) who stated that plants from the treatments that had minimum moisture limits showed lower total dry mass, and stem and branches dry mass than plants from the treatment that had high moisture level. This is also supported by Abd El–Atti *et al*. (2000). Wu and Wang (2000) mentioned that water deficit reduced plant shoot dry weight in bean by over 40%.

Results obtained revealed that there was significant influence of fertilizer potassium on shoot dry weight of cowpea plants as P value is less than 0.05 (Table 2).

At both vegetative and harvesting stage increasing levels of potassium increased the shoot dry weight of cowpea. At both stages 175% potassium level significantly increased the shoot dry weight. This may be due to the increased accumulation of dry matter with increasing potassium level. This was strengthened by Bailey and Laidlaw (1998).

At harvest interaction between moisture condition and potassium rates shows significant influence as P value is less than 0.05. At harvest increasing level of potassium significantly increased the shoot dry weight under optimal and sub-optimal condition. In sub-optimal condition increased level of potassium helps to overcome the moisture stress at harvest. Potassium promoted the shoot growth under water stress and helps the plant to overcome moisture stress. This indicated the importance of potassium in promoting shoot dry matter accumulation in cowpea plants (Sangakkara *et al*., 2001).

3.3 Leaf area

The results pertaining to the effect of potassium application on leaf area of cowpea was significantly influenced by soil moisture content with potassium as *P* value is less than 0.05.

Table 3. Effect of Soil Moisture Content and Potassium Rates on the leaf area of Cowpea Plant (cm^2).

Growth stage	**Rate of MOP**	**Moisture condition** **Sub-optimal**	**Optimal**
Vegetative	**125%**	347.202 ± 15.261^{b}	230.535 ± 36.275^{b}
	150%	380.744 ± 23.338^{b}	451.886 ± 25.561^{a}
	175%	515.224 ± 10.746^{a}	452.391 ± 12.318^{a}
	Recommendation	345.658 ± 9.913^{b}	212.113 ± 18.785^{b}
	Moisture content	$P < 0.05$	
	MOP	$P < 0.05$	
	Interaction	$P < 0.05$	
Harvesting	**125%**	505.216 ± 3.050^{b}	669.853 ± 7.598^{b}
	150%	518.771 ± 3.264^{b}	692.100 ± 4.131^{b}
	175%	550.205 ± 6.575^{a}	800.433 ±16.657^{a}
	Recommendation	486.386 ± 3.111^{c}	631.675 ± 5.687^{c}
	Moisture content	$P < 0.05$	
	MOP	$P < 0.05$	
	Interaction	$P < 0.05$	

The values are means of replicates ± standard error

Means with the same letter(s) are not significantly different from each other according to the Duncan multiple range test at 5% significant level.

The results pertaining to the leaf area of cowpea plant indicated that there was a significant influence of soil moisture and potassium on the leaf area of cowpea plants as *P* value is less than 0.05 (Table 3).

The statistical scrutiny of the data with respect to leaf area of cowpea indicated that potassium level exerted significantly higher increase in leaf area in both moisture conditions at both growth stages. At vegetative stage 175% potassium level increased the leaf area of cowpea under sub-optimal moisture condition. This indicates that potassium promoted leaf development and expansion of cowpea under water stress. Sangakkara *et al*. (2001) stated that application of potassium increased the leaf area of cowpea to a greater extent under sub-optimal soil moisture. Under optimal moisture condition highly significant difference was observed at 150% and 175% potassium levels. It shows that potassium also increase the leaf area of cowpea under optimal soil moisture. Islam *et al*. (2004) stated that irrespective of the levels of water stress, increasing levels of fertilizer potassium increased the leaf area significantly. At harvest increasing potassium levels increased the leaf area significantly. 175% potassium level increased the leaf area highly under optimal and sub-optimal conditions. This indicates that potassium helps plants to overcome water stress by osmoregulation in plant cells (Walker *et al*., 1998). But the leaf area obtained at the optimal moisture condition was greater than the sub-optimal. Similar results were obtained by Islam *et al*. (2004), who stated that smallest leaf area is recorded in the plants grown under severe water stress. This indicates that as water deficits developed, leaf water potential decreased, leaves lost turgor and leaf area was reduced dramatically due to wilting. Significantly lowest values were observed at recommended rate of potassium at both moisture conditions.

CONCLUSION

The present study addressed several aspects of soil moisture content and rate of fertilizer potassium on growth performance of cowpea in sandy regosol soil. From the experiment, it would be possible to conclude that, among the combinations potassium rate at 175% of recommendation at sub-optimal moisture level improved cowpea tap root length and potassium rate at 175% of recommendation at optimal moisture level highly improved cowpea shoot dry weight and leaf area and it also increased the shoot dry weight and leaf area under sub-optimal moisture compared to recommended rate of potassium.

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