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Research Paper

Effect of Potassium Polyacrylamide Acrylate Polymer and Watering Regime on Seedling Growth of Mango (*Mangifera indica*) and Moringa (*Moringa oleifera)* in Minna, Nigeria

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The research was carried out to determine the effect of potassium polyacrylamide acrylate polymer (PPAP) and watering regime on seedling growth of Mango (*Mangifera indica*) and Moringa (*Moringa oleifera)* plantation. This study was undertaken at the Fruit Progeny Garden Department of Crop Production, Federal University of Technology, Minna. Two factors were evaluated, namely; five levels of PPAP and watering regimes. The levels of PPAP were 0, 5, 10, 15, 20 g/plant and the four watering regimes were - field capacity (FC); (¾ FC); ($^1/_2$ FC) and (¼ FC). The experiment was laid out using a split-plot design with watering regimes of as main plot factor and PPAP levels as sub-plot factor with three replicates. The data collected were subjected to analysis of variance (ANOVA) using SAS and where significant difference among treatments was obtained, means were separated using Least Significant Different (LSD) and Duncan Multiple Range Test (DMRT). The results revealed that the application of PPAP into the soil at 10-15 g significantly increased the growth of mango seedlings compared to untreated soil. The results also shows that PPAP application at 10 g by weight into the soil increased the plant seedling height, number of leaves and leaf area except when the concentration of PPAP was increased to 15 g that the stem girth of mango seedling tended to increase in size. Results also revealed that watering regime at ¼ FC was more effective in enhancing seedling growth than other treatments. It was also observed that PPAP did not have a significant effect on moringa seedlings at all stages. While watering regime at field capacity (FC) showed significant response in moringa seedling at all stages. It is recommended that 10 g / plant of potassium polyacrylamide acrylate polymer would adequately sustain growth of mango seedling at the early with a reduced irrigation frequency to survive water stress. Water at one (¼) is recommended for mango seedlings at early stage of production.

Key word: *Moringa oleifera, Mangifera indica,* Watering regime, Polyacrylamide acrylate polymer.

INTRODUCTION

Moringa oleifera, also known as horse radish belongs to the *Moringaceae* family. It is a fast growing deciduous tree indigenous to the sub-Himalayan region of India and is considered as one of the most useful trees in the world. Several parts of the tree are edible and others can be used medicinally (Selvam and Brama, 2005). *Moringa oleifera* is drought-resistant and sensitive to water logging and frost. *Moringa oleifera* tolerates a wide range of rainfall with minimum annual rainfall requirement estimated at 250 mm and maximum at over 3000 mm. It is adapted to various soil conditions, although it grows best in sandy soils and a pH of (5 – 9), (Hsu *et al*., 2006). *Moringa oleifera* is grown widely in Africa where it is used solely around houses to form hedges or to give shade. It came to Nigeria from Niger Republic who eat moringa leaves as a vegetable (Tougiani and Mahamane, 2005).

Mango (*Mangifera indica*) is an evergreen plant of the family *Anacardiaceae*, commonly known as “King of fruits” and a native of southern Asia, especially Burma and Eastern India (Habib *et al*., 2007). According to Food and Agricultural Organization (1999) mango cultivation has been extended to nearly 100 countries in the tropical and sub-tropical regions of the world. India is the world leading producer with China, Mexico, Thailand, Philippines, Nigeria, Indonesia, Brazil and Egypt providing up to 40% of the market in descending order. Mango is cultivated for its fruit which is one of the most highly priced of tropical fruits. It is so abundant that it has also been called “the apple of the Orient”. Mango was ranked second to banana among fruit crops and the fifth overall in the world in terms of tropical agricultural production in 1996 and currently ranked second to pineapple in quantity and value (Gil *et al*., 2000; FAO, 2003).

Mango fruit is among the many fruits consumed for their potential health benefits including anticancer and antiviral activities and reduced risk of cardiac disease associated with antioxidant activities of polyphenolic and carotene compounds. Mango fruits also plays an important role in balancing the diet of human beings by providing about 6,486 calories and other nutrients (Habib *et al*., 2007).

Potassium polyacrylamide acrylate polymer, a superabsorbent polymer with trade name of Super Agrisorb Plus is one of the resources that can store extra water in the soil and enable plants to utilize that water over an extended period of time. Manufacturers’ recommended rate of PPAP for tree crops production varies between 20 to 30 g per plant in mango production (IITA, 2004).

Statement of the problem

Soil and water conservation is essential for sustaining food production and preserving the environment. Therefore, agricultural lands should be managed in a sustainable way and used according to land use capability in order to ensure reasonable standard of efficient production for a long time (Graber *et al*., 2006). Drought stress is considered as one of the main problems of crop production in the northern part of Nigeria. It is usually one of the important reasons for the reduction of performance of crops in this part of the country. Water stress caused by a soil water deficit is one of the major natural limitations of the productivity of natural and agricultural ecosystems, resulting in large economic losses in the country. Kaydan and Yagmur (2008), reported that water deficient conditions decreased seedling growth with higher negative effects such as lower root and shoot length. Duman (2006), declared that water deficit stress decrease root length of lettuce seedling. Root length is an important trait against drought stress in plant varieties; in general, variety with longer root growth has resistant ability for drought. Fernandez (2007), indicated that information about the response of plants to rainfall events in some arid areas is often lacking. The effect of drought on plant is complex and plants respond with many protective adaptations. During drought, the plant suffers from dehydration of its cells and tissues as well as from a considerable increase in the temperature of its body. In the past, irrigation has been a key solution to resolving this problem, but due to the increasing societal demands for water, today it is not a reasonable alternative.

Justification

Soils in the northern part of Nigeria are mostly characterized by low water-holding capacity and high evapo-transpriation which lead to poor water use efficiency by crops. As a result, most tree seedlings that are raised during dry season suffer drought. In light of this, there is often poor seedling establishment and survival in the first year after transplanting. Successfully establishing a transplanted tree depends primarily on rapid root generation. Most newly planted trees are subject to stress-related problems due to tremendous root loss when dug out at the nursery. To a greater or lesser degree, transplant shock lasts until the natural balance between the root system and the top or crown of the transplanted tree is restored. Most of the newly planted trees that do not survive die during this root-establishment period. A tree’s chance of survival can be drastically improved through practices that favor establishment of the root system (Watson, 1986). In arid and semiarid regions of the world, use of PPAP may effectively increase water and fertilizer use efficiency in crops. When polymers are incorporated in soil, it is expected that they retain large quantities of water and nutrients, which are released as required by the plant. Thus, plant growth could be improved with limited water supply (Islam *et al*., 2011). The potting mixture used in nurseries needs to be well drained while at the same time having good water retention. Unfortunately, good drainage is usually associated with poor water retention thereby necessitating frequent watering. In Nigeria, no field research has been conducted on the effect of PPAP on seedling growth of tree crops especially in the Southern Guinea Savanna area.

The aim of this study was to investigate the effect of potassium polyacrylamide acrylate polymer and watering regime on seedling growth of *Moringa oleifera* and mango.

MATERIALS AND METHODS

Physical setting of the experimental site

The experiment was conducted during 2011 and 2012 at the Fruit Progeny Garden of Department of Crop production in Federal University of Technology, Gidan Kwano Campus, Minna (6° 30 E and 9° 40 N).

Rainfall (mm) and temperature (°C) data during the period of seedling growth

The data on weather parameters such as rainfall (mm) and mean maximum and minimum temperature (°**C**) recorded at Nigerian Meteorological Agency (NIMET) Federal Ministry of Aviation, Minna 2011-2012, during the experimental year are presented in (Table 1).

Table 1. Rainfall (mm) and temperature (ºC) data for Minna (2011 – 2012).

Month	Rainfall (mm)		Temperature (ºC)	
	2011	2012	2011	2012
January	0	0	34.7	35.0
February	1.5	0	37.4	37.4
March	0	0	39.3	39.3
April	25.8	34.2	37.2	36.4
May	140.4	204.5	33.4	32.7
June	67.3	96.5	31.4	31.0
July	196.7	333.1	30.7	29.1
August	160.4	376.9	29.4	28.2
September	301.8	337.2	30.3	29.8
October	100.8	158.0	31.4	31.7
November	0	0	36.5	35.5
December	0	0	35.1	36.4
Average	82.9	128.4	33.9	33.5

Source: Nigerian Meteorological Agency (NIMET), Federal Ministry of Aviation, Minna 2011-2012.

Experiment started from September 2011 to June 2012, base on this, the maximum rainfall of 301.8 mm was received in September 2011 followed by May (204.5 mm) in 2012. The months of November, December, January, February and March did not received any rainfall during the experimental period. The mean maximum temperature ranged from 39.3°**C** (March) to 35.0°**C** (January) in 2011- 2012.The months of November, February and March were the hottest. The mean minimum temperature ranged from 30.3°**C** (September) in 2011 to 31.0°**C** (June) in 2012.

Determination of soil characteristics in experimental sites

Soil sample of top-soil was collected from the nursery and at the middle of the experimental field a depth of 0 – 15 cm. The samples were air-dried, gently crushed to pass through a 2 mm sieve. Particle size distribution was determined using Bouyoucos method (Gee and Bauder, 1986). Organic carbon was determined using Walkey Black wet oxidation method (Nelson and Sommers, 1982). Total nitrogen was determined using modified Kjeldahl method (Jackson, 1967). Available P was determined using ascorble acid molybdate blue colour method (Murphey and RIley, 1962). Exchangeable bases (Na^+ and K^+ were determined using flame photometer method (Jackson, 1967). Titration method was used to determine Mg^{2+} and Ca^{2+} (Mclean, 1965). Exchangeable acidity cmol kg^{-1} was determined using KCl extraction method.

Experiments

There were two experiments in the study.

Experiment 1

Effect of potassium polyacrylamide acrylate polymer (PPAP) and watering regime on seedling growth of mango (*Mangifera indica*) in Minna.

Treatment and experimental design

Two factors were evaluated in this study, namely; five levels of PPAP and four watering regimes. The levels of PPAP were 0, 5, 10, 15, 20 g / plant and the watering regimes were (field capacity (FC), (¾ FC), (1/2 FC) and (¼ FC). The different concentrations of PPAP were mixed with 5 kg soil and filled into the polythene pot after which seedlings were transferred from the nursery bed into the polythene pot using naked root method at the age of 24 weeks after sowing. The nursery arrangement was in 4 x 5 factorial fitted into Completely Randomized Design with watering regimes as main plot factor and PPAP levels as sub-plot factor with three replicates. Each sub-plot factor contained 5 seedlings giving a total of 25 seedlings in each main plot.

Source of seeds

Seeds of *M. indica* and *M. oleifera* were obtained locally from Gidan Mangoro along Minna-Bida road, a village near Federal University Technology, Minna gate Gidan Kwano.

Nursery practices

The mango seeds were sown into a prepared bed on 4th May, 2011 and seedlings were uniformly watered. Seedlings were transferred into the treated soil in polythene pot on 26th September, 2011 and also watered from the months of October 2011 – February 2012 before the different watering regimes were imposed at 36 weeks after sowing. Thereafter, the different watering regimes were applied at two weeks interval from March to June 2012. Weeding was done manually to keep the plots weed-free.

Data collection

Three seedlings from each sub-pot were selected and tagged; heights of these seedlings were measured and recorded in centimeters. The measurement was done by using metal tape from the ground level to terminal growing point of the shoot. The total number of plant leaves were counted throughout the period of data collection. The maximum length and breadth of full leaflet were measured using steel ruler and the area of individual leaf was calculated using linear measures (Spann and Heerema, 2010). The stem girth of the tagged seedlings was measured in centimeter using Vernier calipers.

Statistical analysis

The data on various parameters were subjected to analysis of variance (ANOVA) using the statistical analysis software program (SAS, 2002) and means were separated using Least Significant Difference (LSD) and Duncan Multiple Range Test (DMRT).

Experiment 2

Effect of Potassium polyacrylamide acrylate polymer (PPAP) and watering regimes on seedling growth of *Moringa oleifera* in Minna, Nigeria.

Treatment and experimental design

In this experiment, five levels of PPAP and four watering regimes were evaluated.
The levels of PPAP were 0, 5, 10, 15, 20 g / plant and the watering regimes were field capacity (FC), ¾ FC, ½ FC and ¼ FC. The experiment was laid out using split-plot design with watering regimes as main plot factor and PPAP levels as sub-plot factor with three replicates. Each sub- plot factor contains five seedlings giving a total of 25 seedlings in a main –plot factor.

Nursery practices

The different concentrations of PPAP were mixed with 5 kg soil in polythene pot on 28th September, 2011 and one seed of *M. oleifera* was sown directly into each of the polythene pot on 1st October, 2011 and nurtured for five months.

Cultural practices

Weeds present in experimental field were cut manually using cutlass. Holes were dug manually to a depth of 50 cm using spade and digger prior to transplanting; each hole was wetted so as to provide optimum moisture in the soil. At 20 weeks after sowing *Moringa oleifera* seedlings were transplanted into the experimental field and were carried out on 11th February, 2012 and watered uniformly for 21 days. Construction of bunds round each plant was carried out at 20 days after transplanting. The bunds helped to hold water at the base of each plant. Thereafter, the different watering regimes were applied at two weeks interval from of March to June 2012. Hand weeding was done when necessary to keep the plots weed free.

Determination of field capacity in this experiment

Soil cores were saturated by immersing them inside water in a bowl with the water level slightly below the top of the soil cores. The bottom of each coring cylinder has to be covered with cloth to retain the soil. This is followed by determining their water content using the oven-drying method. The formula below is then used to obtain field capacity (FC) from the measured soil cores.

$FC = 0.79\,(SP) - 6.22$ ($r = 0.972$) SP = saturation water % (Mbagwu and Mbah 1998).

Where:
FC = Field Capacity
SP = Saturation water

Data collection

The height of all the *M. oleifera* seedlings was recorded in centimeters by measuring the height with metal tape from the ground level to terminal growing point of the shoot.

Main branches and secondary branches of each *M. oleifera* seedlings were counted. The stem girths of the three hundred seedlings were measured in centimeter using Vernier calipers.

Statistical analysis

The data of various parameters were subjected to analysis of variance (ANOVA) using the SAS program and means were separated using Least Significant Difference (LSD) and Duncan Multiple Range Test (DMRT).

Table 2. Physico chemical properties of the nursery soil and field soil.

Soil Variable	Nursery soil (Top-soil)	Field soil (0- 15cm depth)
Sand (g/kg^{-1})	88.2	85.92
Silt (g/kg^{-1})	8.35	6.00
Clay (g/kg^{-1})	3.44	8.08
Textural class	Loamy sand	Loamy sand
pH (1:2:5 soil water)	6.56	7.25
pH (1.2.5 $CaCl_2$)	5.17	6.84
Organic Carbon (g/kg^{-1})	1.10	0.9 /1.55
Total Nitrogen (g/kg^{-1})	0.029	0.5
Available Phosphorus (mg kg^{-1})	1.20	44.16
Exchangeable Bases (cmol kg $^{-1}$)		
Na^+	0.17	0.067
K^+	0.25	0.085
Mg^{2+}	5.00	0.4
Ca^{2+}	0.98	1.52
Exchangeable acidity (cmol kg^{-1})	0.50	0.20

Table 3. Main effect and interaction of watering regime and potassium polyacrylamide acrylate polymer (PPAP) on seedling height (cm) and stem girth (cm) of mango.

Factor level/interaction	Plant height (cm)				Stem girth (cm)			
	3 WAT	6 WAT	9 WAT	12 WAT	3WAT	6 WAT	9 WAT	12 WAT
Water regimes (w)								
1 Field capacity	29.0a	28.7b	30.7a	30.6b	0.53b	0.99a	0.69a	0.63b
¾ Field capacity	32.0a	34.1a	34.7a	33.7ab	0.53a	0.67a	0.72a	0.69b
½ Field capacity	30.0a	33.2ab	34.9a	34.8a	0.62a	0.66a	0.77a	0.79a
¼ Field capacity	31.7a	29.3ab	32.6a	36.0a	0.62a	0.66a	0.68a	0.68b
SE±	1.5	1.7	1.5	1.4	0.02	0.02	0.03	0.03
PPAP / g / plant (P)								
0	30.0b	25,5cd	26.0d	26.9c	40.84b	43.31c	44.89b	42.42cd
5	29.2.b	22.1d	24.8d	21.7d	39.32b	52.81bc	39.39b	37.52d
10	40.3a	43.2a	44.7a	48.8a	70.92a	68.36a	67.10a	57.19ab
15	31.9b	36.6b	38.9b	41.1b	62.00a	57.65a	61.95.a	67.00a
20	30.3b	29.2c	31.7c	30.5c	46.25b	46.07c	49.25b	50.84bc
SE±	1.7	1.9	1.7	1.6	4.4	4.0	3.6	3.6
W x P	NS	*	*	*	NS	NS	*	*

Means followed by the same letter(s) within a set of treatment column are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). WAT---weeks after treatment, SE – Standard Error.

RESULTS

Physico-chemical properties of the nursery soil and field soil

The analytical results for selected properties of soils used in this study are shown in (Table 1). The soil had a textural class of loamy sand and low total nitrogen content. The available P content and total organic carbon was moderate. Table 2 above shows the main effect and interaction of water regime and potassium polyacrylamide acrylate polymer (PPAP) on seedling height (cm) and stem girth (cm) of mango. At watering regime, no significant difference was recorded in seedling height at 3 and 9 WAT, but 6 and 12 WAT recorded a significant effect. At 6 WAT, there was significant increase when water at ¾ FC was applied and there was no significant differences between other treatments at all the stages. While at 12 WAT, watering regimes at ½ FC and ¼ FC recorded significant increase (34.8 and 36.0) respectively. There was no significant differences between the rest of the treatments as shown in (Table 3) above. At PPAP application levels, significant differences were observed between the treatments with respect to seedling height at all stages. At 3 WAT, 10 g / plant of PPAP recorded higher seedling height (40.3), while other treatments were the same. At 12 WAT, the best result was observed when 10 g of PPAP was applied to the soil

Table 4. Main effect and interaction of watering regime and potassium polyacrylamide acrylate polymer (PPAP) on number of leaves and leaf area (cm^2) of mango.

Factor level/interaction	Number of leaves				Leaf area (cm^2)			
	3 WAT	6 WAT	9 WAT	12 WAT	3WAT	6 WAT	9 WAT	12 WAT
Water regimes (w)								
1 Field capacity	13.83a	23.36a	15.07b	18.00b	48.26a	55,29a	48.95a	50.21ab
¾ Field capacity	14.36a	24.00a	20.00a	23.00a	53.84a	50.00a	51.79a	45.10b
½ Field capacity	15.62a	25.16a	20.00a	19.22b	53.68a	54.35a	56.58a	57.00a
¼ Field capacity	14.05a	25.07a	21.00a	25.17a	51.71a	55.22a	53.00a	50.64a
SE±	0.8	2.1	0.8	0.9	4.0	3.6	3.2	3.2
PPAP / g / plant (P)								
0	13.00b	13.59c	13.21c	13.37c	40.84b	43.31c	44.89b	42.42cd
5	11.08b	21.12b	13.38c	13.33c	39.32b	52.81bc	39.39b	37.52d
10	19.00a	30.74a	25.00a	31.33a	70.92a	68.36a	67.10a	57.19ab
15	16.65a	29.70a	23.03a	30.00a	62.00a	57.65a	61.95.a	67.00a
20	12.82b	26.71a	18.54b	18.57b	46.25b	46.07c	49.25b	50.84bc
SE±	0.9	2.3	2.7	11	4.4	4.0	3.6	3.6
W x P	*	NS	*	*	*	*	*	NS

Means followed by the same letter(s) within a set of treatment column are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). WAT---weeks after treatment, NS--- not significant at 5% level of probability, *significant at 5% level of probability

and the untreated soil gave the least value of seedling height (Table 3). The interaction effect of watering regime and PPAP were generally significant except at 3 WAT.

In stem girth of mango seedlings, 6 and 9 WAT recorded no significant differences between the treatments at all stages. At 3 and 12 WAT, ½ FC recorded higher seedling which was at par with ¼ FC at 3 WAT; while other treatments were similar. However, PPAP level of 10 g and 15 g / plant shows no significant difference at all stages and recorded wider stem girth compared to all the treatments. Other treatments were on par with each other except at 5 g of PPAP in 12 WAT. The interaction between water regime and PPAP shows significant effect at 9 and 12 WAT and there was no significant different was recorded at 3 and 6 WAT.

Table 3 shows the effect and interaction of water regime and potassium polyacrylamide acrylate polymer (PPAP) on plant number of leaf and leaf area (cm^2) of mango seedlings. Water regime factor shows no significant difference in number of leaves at 3 and 6 WAT but significant variations were recorded at 9 and 12 WAT. At 9 WAT, water regime at field capacity (FC) resulted in a significant decrease in number of leaves and at 12 WAT similar thing at ½ FC at 12 WAT. A very significant increase was recorded in the number of leaves as the concentration of PPAP to the soil increased to 10 g – 15 g at all stages. In addition, the interaction between watering regime and PPAP levels indicated high significant differences even with significant at 1% level of probability at 9 WAT.

Leaf area increased significantly from 3 to 9 WAT in all treatments with slight changes at FC and 3/4 at 12 WAT. At PPAP levels there were significant variations in leaf area of mango seedling. At all stages, 10 to 15 g/plant recorded higher leaf area compared to all the treatments. Significant effects were recorded in the interaction between water regime and PPAP except at 12 WAT.

Table 4, shows the interaction between water regime and potassium polyacrylamide acrylate polymer (PPAP) of seedling height of mango at 6, 9 and 12 WAT. AT 6 WAT, watering regime at full field capacity (FC) resulted in significant difference in seedling height of mango when potassium polyacrylamide acrylate polymer was increased from 0 to 15 g/ plant, beyond which there was a significant decline. Watering at ¾ FC recorded significant increase in seedling height when 10 g / plant of potassium polyacrylamide acrylate polymer was applied, beyond which there was no significant differences. Furthermore, watering at ½ FC shows that 10 g / plant of PPAP application gave the tallest height while other treatments differed significantly. Water regime at ¼ FC, the application of PPAP at 10 g / plant also produced the tallest seedling height more than 15 and 20 g / plant, 0 and 5 g / plant were similar. Potassium polyacrylamide acrylate polymer at 10g/plant gave the highest value of seedling height when the ¾ FC was applied and there was no significant difference among other treatments except at FC. In addition, PPAP at 15 g / plant, the use of ½ FC differed significantly with all other treatments, while FC, ¾ FC and ¼ FC shows no significant difference among themselves. PPAP level at 20 g / plant shows significant differences at various level of watering regime. There were also significant differences at PPAP level of 0 and 5 g/ plant at different level of watering regime. Generally, watering regime at ¾ FC together with 10 g / plant of PPAP level gave the tallest seedling height and the least was watering regime at ¼ FC and 0 g / plant of PPAP.

At 12 WAT, watering regime at full field capacity increased the seedling height when PPAP level was

Table 5. Interaction between watering regime and potassium polyacrylamide acrylate polymer on seedling height of mango at 6, 9 and 12 wat in 2012.

	Potassium Polyacrylamide acrylate polymer (PPAP) levels				
	0	**5**	**10**	**15**	**20**
Water regime (w)	6 WAT				
Field capacity	31.3de	24.5g	33.3ce	36.2c	18.2h
¾ Field Capacity	26.3fg	29.5ef	48.7a	35.0cd	30.9def
½ Field Capacity	29.3ef	17.8h	45.5ab	41.2b	32.3cde
¼ Field Capacity	14.9h	16.6h	45.3ab	33.9cde	35.5cd
SE ±			4		
Water regime (w)	9 WAT				
Field capacity	31.5efgh	25.2jk	38.8de	33.7def	28.3hij
¾ Field Capacity	27.0ij	30.0fghi	50.7a	36.6d	29.5ghi
½ Field Capacity	29.7fghi	22.4k	46.7ab	42.2c	33.3defg
¼ Field Capacity	16.0i	21.7k	46.7ab	43.2bc	35.7d
SE ±			3.36		
Water regime (w)	12 WAT				
Field capacity	33.2ef	15.3i	38.8d	37.5d	28.2gh
¾ Field Capacity	27.gh	29.8fg	51.2ad	35.2de	25h
½ Field Capacity	29.8fg	17.2i	50.7ab	43.7c	32.5ef
¼ Field Capacity	17.5i	24.7h	53.5a	48.2b	36.2de
SE ±			3.11		

Means followed by the same letter (s) within a set of treatment column and between rows are not significantly different at 5% level of probability using DMRT.

increased from 10 g / plant to 15 g / plant. While other treatments shows significant differences. Furthermore, watering at ¾ FC recorded higher seedling height at 10 g / plant of PPAP which was on par with ½ FC and also did not differ significantly with ¼ FC. There were no significant differences observed between the rests of the treatments. Similarly, potassium polyacrylamide acrylate polymer at 0 g / plant differed significantly in all the stages. PPAP at 5 g / plant there was increase in seedling height when ¾ FC was applied beyond which there was a significant decline. In addition, PPAP level at 10 g / plant, the use of ¼ FC produced a good result in seedling height as shown in (Table 4). There was no significant difference between other treatments except at FC. At 15 g / plant, the use of ¼ FC also resulted in increase in seedling height. Similarly, watering regime at ¼ FC together with 10 g / plant produced the tallest seedling height while the smallest seedling height was obtained from watering regime at FC together with 5 g / plant. These variations in watering levels could be as a result of rainfall interruption during the month of May 2012.

Table 5 shows the interaction between water regime and potassium polyacrylamide acrylate polymer on stem girth of mango seedling at 9 and 12 WAT. At 9 WAT, watering at field capacity, resulted in significant increase in stem girth when PPAP level was increased from 10 g /plant to 15 g / plant. Similarly watering at ¾ FC showed increase in stem girth at 0 g, 10 g, and 20 g / plant, while there was a significant difference between 5 g and 15 g / plant. In addition, watering at ½ FC indicated significant increase in stem girth at PPAP level of 10g / plant besides; there were significant differences between other treatments. Watering at ¼ FC, the use of PPAP level at 10 g, and 15 g / plant produced the widest stem girth. At PPAP level of 0 g / plant, stem girth of mango seedling was widest when ¾ FC was applied while ¼ FC produced the least value of stem girth. At PPAP level of 5 g / plant the widest stem girth was obtained at watering regime of ½ FC. Similarly, PPAP level at 10 g / plant significantly increased stem girth when ½ FC was applied and there were significant differences between other treatments. Furthermore, PPAP level at 15 g / plant, ½ FC recorded increased in stem girth which was the same with ¼ FC and significant differences were observed between FC and ¾ FC. Generally, there were significant variations in both watering regime and PPAP levels. Nevertheless, watering regime at ½ FC together with PPAP level at 10 g / plant produced the widest stem girth of mango seedling.

At 12 WAT, water regime at FC showed increase in stem girth when PPAP level was increased from 10 g / plant to 15 g / plant, there was significant differences among others. While watering at ¾ FC resulted in increase in stem girth when the application of PPAP level was at 10 g / plant, there was no significant response among other treatments. At ½ FC, the application of PPAP level at 10 g / plant produced the widest stem girth beyond which there was a significant decline. In addition, as water regime decreases from ¾ FC to ¼ FC a wider stem girth was produced.

However, at PPAP level of 0 g and 10 g /plant, varying

Table 6. Interaction between watering regime and potassium polyacrylamide acrylate polymer on plant stem girth of mango seedlings at 9 and 12 wat in 2012.

	Potassium Polyacrylamide acrylate polymer levels				
	0	**5**	**10**	**15**	**20**
Water regime (w)	9 WAT				
Field capacity	0.6e	0.7d	0.8c	0.8c	0.6e
¾ Field Capacity	0.8c	0.6e	0.8c	0.7d	0.8c
½ Field Capacity	0.7d	0.8c	1.0a	0.9b	0.6e
¼ Field Capacity	0.4g	0.5f	0.9b	0.9b	0.7d
SE±			0.07		
Water regime (w)	12 WAT				
Field capacity	0.6e	0.5f	0.8c	0.8c	0.5f
¾ Field Capacity	0.7d	0.5f	0.9b	0.7d	0.7d
½ Field Capacity	0.9b	0.6e	0.9b	1.1a	0.7d
¼ Field Capacity	0.4g	0.6e	0.8c	0.9b	0.7d
SE ±			0.07		

Means followed by the same letter (s) within a set of treatment column and between rows are not significantly different at 5% level of probability using DMRT.

the watering regime from FC to ½ FC produced the widest girth beyond which there was a significant decline. At PPAP level of 5 g / plant varying the water regime from ½ FC to ¼ FC produced a good stem girth while FC and ¾ FC show no significant difference. At 15 g / plant, the application of watering at ½ FC gave the widest stem girth more than the rest of the treatments. Generally, watering at ½ FC combined with 15 g / plant of PPAP produced the widest stem girth while watering at ¼ FC together with 0 g / plant gave the least value.

Table 6 shows the interaction between water regime and potassium polyacrylamide acrylate polymer on number of leaves of mango seedling at 3, 9, and 12 WAT. At 3 WAT, watering at FC showed increase in the number of leaves at the application of 0 g / plant and differed significantly with the rest of the PPAP level treatment. At ¾ FC the number of leaves was more at PPAP level of 10 g / plant as compared to other treatment. Furthermore, watering at ½ FC, the use of PPAP level at 10 g / plant significantly differed from other treatments and recorded higher number of leaves. In addition, watering at ½ FC, the application of 10 g / plant also gave a good number of leaves beyond which there was a significant decline. PPAP level of 0 g / plant showed significant increase in the number of leaves when watering regime at FC was used and other treatment differed significantly. At PPAP level of 5 g / plant, higher number of leaves was obtained when ¼ FC was used and no significant difference between FC and ¾ FC. Similarly, with PPAP at 10 g / plant the application of ¾ FC and ½ FC gave the highest number of leaves beyond which there was a significant decline. At 15 g / plant, watering at ½ FC produced the highest number of leaves more than FC, ¾ FC and ¼ FC. PPAP at 20 g / plant, the use of ¼ FC gave a higher number of leaves among other treatments. Above all, watering regime at ½ FC in conjunction with 10 g / plant produced the highest number of leaves.

At 9 WAT, watering regime at FC indicated that an increase in the concentration of PPAP from 0 g to 10 g / plant increased the number of leaves while there was a significant variation among other treatments. Watering regime at ¾ FC increased the number of leaves significantly when 10 g/ plant were used. In addition watering at ½ FC showed that PPAP level 10 g and 15 g / plant produced the highest number of leaves while other treatment differed significantly. Watering at ¼ FC, the application of 10 g and 20 g / plant gave the highest number of leaves. PPAP levels of 10 g to 20 g / plant, varying the watering regime from ¾ FC to ¼ FC increased the number of leaves significantly. With PPAP level at 0 g / plant the highest number of leaves was obtained when FC was applied beyond which there was a significant decline. At 5 g / plant, ¾ FC and ½ FC did not differ in value while FC and ¼ FC differed significantly. Generally, watering regime from ¾ FC to ¼ FC together with PPAP level from 10 g to 20 g / plant significantly increased the number of leaves.

At 12 WAT, watering regime at FC the number of leaves significantly increases when PPAP level was increased from 0 g to 10 g / plant which gave equal value with 15 g / plant while other treatments differed significantly. Number of leaves significantly increased at ¾ FC when PPAP level was at 10 g / plant while other treatments showed significant decline. Furthermore, when watering regime was at ½ FC, the number of leaves increased at the application of PPAP levels at 10g and 15 g / plant which differed significantly with the rest of the treatments. Watering at ¼ FC gave the highest number of leaves at the application of 10 g / plant and 15 g / plant compared to other treatments. Potassium polyacrylamide acrylate polymer at 0 g / plant increased

Table 7. Interaction between watering regime and potassium polyacrylamide acrylate polymer on number of leaves of mango seedlings at 3, 9 and 12 wat in 2012.

	Potassium Polyacrylamide acrylate polymer levels				
Treatment	**0**	**5**	**10**	**15**	**20**
Water regime (w)	3 WAT				
Field capacity	18.5bc	10.8ij	15.7def	15.0efg	9.2jk
¾ Field Capacity	10.3ij	10.0jk	20.8ab	17.5cd	13.2gh
½ Field Capacity	14.8efg	9.5ij	21.0a	20.5ab	12.3hi
¼ Field Capacity	7.8k	14.0fgh	18.2c	13.7fgh	16.7cde
SE ±			1.8		
Water regime (w)	9 WAT				
Field capacity	17.8e	9.5ij	18.7df	17.7e	11.7hi
¾ Field Capacity	11.3hi	14.0fg	27.5a	22.3bc	20.8cd
½ Field Capacity	15.2f	14.7fg	26.8a	28.5a	12.8gh
¼ Field Capacity	8.5j	15.3f	26.7a	23.7b	28.8a
SE ±	1.86				
Water regime (w)	12 WAT				
Field capacity	16.2ef	12.5h	23.8b	23.8d	13.0gh
¾ Field Capacity	13.7fgh	16.3e	34.3b	28.3c	21.3d
½ Field Capacity	13.8efgh	8.2i	29.2c	29.5c	15.5efg
¼ Field Capacity	9.8i	16.3e	38.0a	38.0a	23.7d
SE ±	2.11				

Means followed by the same letter (s) within a set of treatment column and between rows are not significantly different at 5 % level of probability using DMRT.

the number of leaves at the application of FC beyond which there was no significant response. At PPAP level of 5 g / plant with watering regimes at ¾ FC and ¼ FC produced an increase in the number of leaves while the rest differed significantly. As PPAP application increased from 10 g to 15 g / plant resulted in significant increase in the number of leaves at watering regime of ¼ FC as shown in Table 6. Above all, watering regime at ¼ FC in combination with 10 g and 15 g / plant produced the highest number of leaves while watering at ¼ FC together 0 g / plant apparently gave the smallest number of leaves.

Table 7 shows the interaction between watering regime and potassium polyacrylamide acrylate polymer on leaf area of mango seedling at 3, 6 and 9 WAT. At 3 WAT, watering regime at FC shows a significant increase in leave area as PPAP level was increased 0 g to 15 g / plant, beyond which there was a significant difference among other treatments. Watering at ¾ FC, 10 g / plant of PPAP application gave the highest leaf area than others. In addition, watering regime at ½ FC, the use of 15 g / plant of PPAP level produced the highest leaf area while significant variations was recorded among other treatment. High result was also obtained at ¼ FC when the application of PPAP level at 10 g / plant was used. PPAP level at 0 g / plant, the use of ¾ FC gave the highest leaf area and the rest treatments differed significantly. PPAP at 5 g / plant, the application of ¼ FC increase the leaf area beyond which there was no significant response. In addition, PPAP level at 10 g / plant and 15 g / plant with different watering regimes at ¾ FC and ½ FC gave the highest leaf area compared to other treatments. 20 g / plant of PPAP significantly increased leaf area and there was no significant difference showed among other treatment. Generally, watering regime decreases from ¾ FC to ¼ FC together with increase in concentration of PPAP level from 10 g to 15 g / plant produced the highest leaf area. While the untreated control recoded significantly lowest leaf area in conjunction with ¼ FC as shown in (Table 7).

At 6 WAT, watering regime at FC significantly increased leaf area when 10 g / plant were used and there were significant variation among other treatments. At ¾ FC, the application of 5 g / plant gave the highest leave area more than other treatments. Similarly, watering at ½ FC, the use of 10 g / plant produced the highest leaf area which differed significantly with the rest of the treatments. Watering at ¼ FC increased the leaf area significantly with the application of PPAP at 10 g / plant and there was no significant difference among others except in 15 g / plant. At PPAP level of 0 g / plant, the use of FC increased the leaf area while the rest treatments differed significantly. At 5 g / plant, leaf area was increased when ¾ FC was used. In addition, PPAP at 10 g / plant resulted in significant increase in leaf area with the application of ¼ FC, beyond which there was significant difference between other treatments. At 15 g / plant, the use of ¼ FC gave the highest leaf area which differed significantly with ¾ and ½ FC. At 20 g / plant, the leaf area was higher than the rest of the treatments when

Table 8. Interaction between watering regime and potassium polyacrylamide acrylate polymer on leaf area of mango seedlings at 3, 6 and 9 wat in 2012.

	Potassium Polyacrylamide acrylate polymer levels				
	0	5	10	15	20
Water regime (w) 3 WAT					
Field capacity	45.6df	39.8f	55.4bcd	62.0bc	38.6f
¾ Field Capacity	53.2cde	39.9f	89.6a	41.8f	45.1df
½ Field Capacity	38.9f	36.1fg	56.4bc	79.4a	57.1def
¼ Field Capacity	25.6g	41.8f	82.4a	64.8b	43.9b
SE ±			8.86		
Water regime (w) 6 WAT					
Field capacity	46.4fg	41.0g	66.3cd	64.2cde	58.6e
¾ Field Capacity	43.6g	68.4bc	45.5g	46.7fg	44.3g
½ Field Capacity	39.0g	61.8cde	76.5ab	55.1ef	39.4g
¼ Field Capacity	44.4g	40.1g	85.1b	64.7cd	41.9g
SE ±			8.03		
Water regime (w) 9 WAT					
Field capacity	46.1fgh	40.7hi	53.9def	59.4cd	44.6gh
¾ Field Capacity	57.0cde	41.8ghi	71.1b	39.2hij	49.9efg
½ Field Capacity	44.9gh	35.4ij	60.8cd	85.5a	56.3cdee
¼ Field Capacity	31.6gh	39.6hij	82.2a	63.2bc	46.3fgh
SE ±			7.26		

Means followed by the same letter (s) within a set of treatment column and between rows are not significantly different at 5% level of probability using DMRT.

FC was applied. Above all, watering regime at ¼ FC in combination with 10 g / plant produced the highest leaf area while watering regime at ½ FC together with 0 g and 20 g / plant gave the lowest leaf area.

At 9 WAT watering regime at FC, the leaf indicated a significant increase when PPAP was increased from 0 g to 15 g / plant more than other treatments. At ¾ FC, showed increase in leaf area as the PPAP level was increased from 0 g to 10 g / plant which differed significantly with other treatments. Similarly, at ½ FC leaf area showed significant increase when PPAP level was at 15 g / plant. Watering at ¼ FC, the application of PPAP from 10 g to 15 g / plant gave the highest leaf area, beyond which there was a significant decline. At PPAP level of 10 g and 15 g / plant varying the watering regime from ½ FC to ¼ FC significantly increased the leaf area of mango seedling. Similarly, at PPAP level of 0 g and 20 g / plant with different watering regime from ¾ FC to ½ FC increased the leaf area, beyond which there was no significant response. In general, watering regime of ½ FC to ¼ FC in collaboration with 10 g / plant and 15 g / plant gave the highest leaf area while watering at ¼ FC produced the lowest leaf area.

Table 8 shows the effect of watering regime and potassium polyacrylamide acrylate polymer on the height (cm), number of branches and sub-branches of moringa seedlings. There were significant increases in plant height (cm) when the soil was irrigated at field capacity (FC). While significant difference was recorded in all the rest of the watering regimes. At PPAP application to the soil, significant increases were recorded in the entire watering regime except at 5 g of PPAP at 9 WAT. The interaction effects of water regime and PPAP levels were generally not significant. Watering regime shows no significant differences in the number of branches when FC and ½ FC were applied to the soil. Water regime at (¾ FC) and (¼ FC) shows significant differences in number of branches. At PPAP levels there were generally significant increase in all levels throughout the seedlings stage. The interaction effect of W X P also did not significant as shown in Table 8. There was significant increase in the number of sub-branches, when field capacity (FC), ¾ FC and ½ FC were applied while ¼ FC indicated significant decline at 6, 9 and 12 WAT except at 3 WAT. PPAP levels show significant increase in all the rest of the period. The interaction also indicated non-significant throughout the study period.

Stem and tip girth were significantly increased at field capacity and only in tip girth at ½ FC, beyond which there were significant decline in other water regimes. At PPAP levels, stem girth shows significant increase except at the application of 15 g at 9 WAT. PPAP applications tend to show variations in response in tip girth except at 10 g and 20 g as shown in (Table 9). The interaction between water regimes and PPAP, show non-significance.

Discussion

In the past, many researchers who worked on the effect of potassium polycrylamide acrylate polymer (PPAP) on crops, only focused on food crops and few cash crops

Table 9. Main effect and interaction watering regimes and potassium polyacrylamide acrylate polymer (ppap) on plant height (cm) of moringa.

	Seeding height (cm)			
TREATMENTS	**3WAT**	**6WAT**	**9WAT**	**12WAT**
Water regime (w)	3 WAT			
Field capacity	74.56a	8.5.12a	94.91a	130.5a
¾ Field Capacity	62.99b	77.07ab	81.59b	118.7b
½ Field Capacity	62.80b	75.79ab	89.72ab	123.5ab
¼ Field Capacity	61.53b	70.53b	82.57b	114.7b
SE±	2.8	3.0	3.8	3.4
PPAP /g/plant (P)				
0	63.47a	78.02a	88.36ab	120.4a
5	63.20a	78.37a	79.28b	121.6a
10	65.05a	72.62a	87.47ab	123.7a
15	65.00a	76.05a	88.78ab	121.2a
20	70.72a	80.58a	92.08a	122.4a
SE ±	3.1	3.4	4.2	3.8
W x P	NS	NS	NS	NS

Means followed by the same letter (s) within a set of treatment column and between rows are not significantly different at 5% level of probability using DMRT. WAT- weeks after transplanting.

excluding mango and *Moringa oleifera* as tree crops. The reason may be due to the fact that both mango and *Moringa oleifera* are sun-loving plants. In the present investigation, there was a significant increase in seedling height in mango due to the application of PPAP into the soil compared to the untreated soil which was in agreement with the following results observed by Sivalapan (2001) in soybean, Sendur *et al*., (2001) in tomato and Patil, (2009) in cabbage. Stem girth was significantly increased in mango by the application of potassium polyacrylamide acrylate polymer (15 g / plant) into the 5kg soil in polythene pot. Anupama *et al.* (2005) also observed an increase in stem diameter in *chrysanthemum* grown in the soil media at 0.5% of PPAP despite the fact that it was directly planted into the soil. Sevenson, (1993) also reported that soil application increased stem length in West Indies mahogany. It was also observed that the application of PPAP (10 g) into the soil significantly increased the number of leaves in mango. Similar result was reported by Anupama *et al.* (2005) in *chrysanthemum* that by the application of PPAP number of leaves increased per plant. Leaf area fairly gives a good idea of the photosynthetic capacity of the plant and decreased leaf area is an early response to water deficit. The results of the present investigation showed that an increase in PPAP concentrates significantly increased the leaf area of mango at 10 to 15 g/plant. Potassium polyacrylamide acrylate polymer (PPAP) significantly reduced the watering frequency in mango seedlings by increasing water holding capacity of soil which is in accordance with the results observed by Abdulaziz and Al-Harbi, (1997), Sivalapan (2001) in soyabean, Cookson *et al.* (2001) in okra and Abedi and Asad, (2006) in *Cupressus*. Throughout the study period we found out that in all the values of each parameter taken were significantly reduced when field capacity was applied to the soil. This really shows that Potassium Polyacrylamide acrylate polymer reduced the irrigation frequency and water requirement of crops with increasing concentration according to Johnson and Leah, 1990).

In this investigation, the interaction of Potassium polyacrylamide acrylate polymer and watering regime shows no significant difference in *Moringa oleifera* seedling throughout the study period. This result confirmed the fact that *M. oleifera* is drought-resistant plant and sensitive to water logging and frost (Hsu *et al.,* 2006). It is also a confirmation of the results observed by Boatright *et al.* (1997) and Ingram and Yeager, (1987) that results of field research on Potassium Polyacrylamide acrylate polymer, to alleviate water stress have been unpredictable. Some researchers reported improved plant growth and reduced irrigation frequency when the soil was treated with PPAP. While others found no significant effect from the addition of PPAP to the soil.

Conclusion

From the present investigation, plant height, stem girth, number of leaves and leaf area of mango seedlings can be increased significantly by the application of Potassium Polycrylamide acrylate polymer into the soil.

The results demonstrated conclusively that watering regime at (¼ FC) was more effective in enhancing seedling growth than irrigating at field capacity (FC), (¾ FC) and half of field capacity respectively.

On the basis of experimental results it could also be concluded that PPAP, did not have much significant difference in *Moringa oleifera* seedlings. It was also indicated that the interaction of water regime and PPAP shows non significant effect in *M. oleifera* seedlings.

Recommendations

(1) It is recommended that 10g of potassium polyacrylamide acrylate polymer would adequately sustain growth of mango seedling at the early stage with reduced irrigation to survive water stress.
(2) Watering at one quarter of field capacity (¼) is recommended for mango seedlings at early stage of production.
(3) It is recommended that even with little or no PPAP applied to the soil, *Moringa oleifera* seedling can still survive water stress at the early stage.
(4) Based on rainfall and temperature data in 2011 and 2012, we suggest that for feature studies, time to carry out experimental research on a topic like this should be considered. The experiment should be done between the month of November and March where the study will not be interrupted by rainfall.

AUTHORS` DECLARATION

We declare that this study is an original research by our research team and we agree to publish it in the journal.

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