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Post-Harvest Storability of Potato Varieties as Influenced by Irrigation Intervals and NPK Rates in Sudan Savanna of Nigeria

A. Muhammad*
Department of Crop Science, Kebbi State University of Science and Technology, Aliero, Nigeria

I. U. Mohammed
Department of Crop Production, University of Maiduguri, Borno State, Nigeria

B. A. Gambo
Department of Crop Science, Usmanu Danfodiyo University, Sokoto, Nigeria

U. Aliyu
Department of Crop Science, Usmanu Danfodiyo University, Sokoto, Nigeria

N. M. Kwaifa
Department of Crop Science, Kebbi State University of Science and Technology, Aliero, Nigeria

*Corresponding author, E-mail: adamubk73@gmail.com, Phone: +2347064853118

***Abstract* – Field trials were conducted during the 2009-12 dry seasons at the Teaching and Research Farm of the Kebbi State University of Science and Technology located at Jega in the Sudan savannah zone of Nigeria. The aim was to study the effects of irrigation interval and NPK rates on storability of three varieties of potato (*Solanum tuberosum* L.). Treatments consisted of three irrigation intervals (3, 6 and 9 days), four rates of NPK (20:10:10) fertilizer (0, 300, 600 and 900 kg NPK ha^{-1}) and three varieties of potato (Bertita, Diamant and Nicola). Factorial combinations of irrigation intervals and fertilizer rates were allocated to the main-plots, while varieties were assigned to the sub-plots in a split plot design, replicated three times. The size of each sub-plot was 4.5 x 3m (13.5m). Result revealed that, high percent rotted tubers were recorded by frequent irrigation of 3 days interval. NPK rate did not affect tuber storability in the study area. Varieties Diamant and Bertita sprouted earlier (indicating short dormancy period) and had higher percentage of sprouted and rotted tubers especially within the first 8 weeks of storage. Based on the result, variety Nicola proved best for post-harvest storability.**

***Keywords* – Post-harvest, Storability, Irrigation Interval, NPK Rate, Potato.**

I. Introduction

Irish Potato (*Solanum tuberosum* L.) originated in the high plains of the Andes Cordillera where it is largely cultivated for food. The Spanish, who conquered Peru, discovered the crop and introduced it to Spain and the west of Europe in the mid- 16th century [1] [2]. In Africa, it was not until the end of the 19th century that potato was imported from Europe by missionaries and the colonial administration [2].

Potato is one of the word's prime sources of human nutrition. The protein/carbohydrate ratio is higher than for most cereals and even higher than those of the other tuber and root crops [3]. In terms of composition, potato tuber contains 70 – 82% water, 17 – 29% dry matter, 11 – 23% carbohydrate, 0.8 – 3% protein, 0.1% fat and 1.1% minerals. Production per hectare of important vitamins, such as thiamine, riboflavin, niacin and vitamin C is higher in potato than in other major crops, such as rice, maize and wheat [2] [3] [4] [5]. According to [3], daily consumption of 1 kg of potato tuber provides all the essential amino acids needed by the body, except cystine and methionine. Potato tubers have been consumed in various forms in developing countries of Africa, including eating in cooked form, incorporation with yam during *pounded yam* preparation and processing into flours along with yams for edible dough such as *amala* in Nigeria [6].

Storage is an important component of potato production. It serves to preserve the tubers and minimize the fluctuation in supply of potato which is the present situation in Nigeria. Potato tubers are highly perishable and difficult to store at temperatures above 20^{o}C for more than 5 months [7]. It has also been reported that farmers lose as high as 40% of their stored seed tubers within 3 months of storage as a result of poor storage conditions. Ware or table potatoes are rarely stored by farmers. They are often sold as soon as they are harvested no matter the prices [3]. Spoilage associated with potatoes resulting to postharvest losses is manifested by a loss of quantity and quality due to pathological, physiological and mechanical damages [8]. As reported [9], potatoes irrigated to fully replace evapotranspiration had higher yields, better grade, fewer physiological defects but poor storage ability. Tuber physiological disorders such as brown center, hollow heart, translucent end, secondary growth, growth cracks, bruise susceptibility and heat necrosis have been associated with water stress and or wide variation in soil moisture content [9]. This study intends to assess the effects of irrigation interval and NPK rates on storability of three potato varieties under the ambient conditions of the study area.

II. Materials and Methods

The experiments were conducted during 2009/10, 2010/11 and 2011/12 dry seasons at the Teaching and Research Farm of the Kebbi State University of Science and Technology at Jega (lat. 120 11' N; long. 40 16' E) in the Sudan savanna ecological zone of Nigeria. The climate of the area is semi-arid with an average rainfall of about 550mm - 650mm per annum. The relative humidity ranges from 21 - 47% and 51 - 79% during the dry and rainy seasons, respectively. The temperature ranges between 14 - 30^{o}C during the dry season and 27 – 41^{o}C during the rainy season [10].

The treatments consisted of three irrigation intervals (3, 6, and 9 days), four rates of NPK (20: 10: 10) fertilizer (0, 300, 600 and 900kg/ha) and three potato varieties (Nicola, Bertita, and Diamant). The treatments were laid out in a split - plot design with three replications. Irrigation intervals and fertilizer rates were combined and allocated to the main plots while variety was assigned to the subplots. The planting material (seed tubers) for the three varieties was sourced from the Potato Program Unit of the National Root Crop Research Institute (NRCRI) sub-station Vom, Jos, Plateau State. The seed tubers were pre-sprouted for six weeks before planting. The seed tubers were dressed with fungicide (Muncozeb powder) a day prior to planting. Planting was done manually with whole or cut tubers of approximately 30g weight per hill at intra-row spacing of 30cm and a depth of 8 – 10cm. Plots of 3.0 x 4.5m (13.5m^2) were marked out, leaving a 1m space between main plots. Each subplot was made into six ridges, 75cm apart. Water channels were constructed for effective supply of water to each furrow during irrigation. The net plot area consisted of the two middle rows (3.0 x 1.5m) (4.5m^2).

The source of water was a tube well. Water pump machine was used to draw water from the source to the field through the constructed water channels. Irrigation was scheduled according to the treatments, at 3, 6 and 9 days interval. The whole field, irrespective of the irrigation treatment, was watered 3 days before and after planting. The irrigation treatment was imposed after the crop has fully emerged [within 3 weeks after planting (WAP)]. Compound fertilizer (NPK 20: 10: 10) was used at the variable treatment rates of 0, 300, 600 and 900kg NPK/ha. These rates were applied according to the treatments in two split doses; the first and second doses were applied at planting and at 4WAP, respectively. The fertilizer was applied at about 10cm away from plant stand and 5cm deep and covered. Weeds were controlled manually using hand-hoe at 4 and 7 WAP. Karate (lambdacyhalothrin) was sprayed at 4mlL^{-1} of water against insect pests. The crop was harvested on 16th February, 2010; 12th February, 2011; and 11th February, 2012; for the 2009/10, 2010/11 and 2011/12 trials, respectively. A light irrigation was given to all plots a day before harvesting irrespective of the irrigation treatment to facilitate easy lifting of tubers.

After harvest, samples of 30 healthy and marketable size tubers were drawn per treatment, and spread out in clean disinfected wooden crates of 30 x 30 x 10 cm dimensions. The containers were stored in a well ventilated store under ambient local conditions and were kept in a completely randomized arrangement. The samples were inspected two-weekly, over a period of 4 months (February-June), and observations on mean weight loss, sprouting and rotted tubers were made at 4 weeks interval. At each inspection, tubers that have sprouted were counted and percent sprouted tubers were calculated. Rotted tubers were also sorted out and the number rotted was expressed as percentage. Weight of the remaining tubers after sorting out the rotted ones was expressed as percent weight loss.

III. Results

Percent Rotted Tubers

At 4 Weeks After Storage (WAS), irrigation at 3 days interval resulted in significantly higher rotted tubers than 9 days interval in 2009/10 dry season. But in 2010/11 and 2011/12 seasons, irrigation interval did not show significant effect on percent rotted tubers (Table 1). Similarly, NPK rate did not show significant effect on percent rotted tubers in all seasons and the combined data. Variety Diamant recorded significantly higher rotted tubers than Nicola while Bertita recorded significantly higher rotted tubers than Nicola in 2009/10. In the combined data, Bertita and Diamant gave more rotted tubers than Nicola.

At 8WAS, effect of treatments on percent rotted tubers was significant only in 2009/10 dry season as presented in Table 1. Irrigation at 3 days interval produced significantly higher percent rotted tubers compared with 9 days. The other two dry seasons (2010/11 and 2011/12) and the combined showed no significant effect. NPK rate did not affect percent rotted tubers throughout the seasons and the combined. Both varieties Bertita and Diamant had statistically the same percent rotted tubers, which were significantly higher than in Nicola in 2009/10 and the combined dry seasons. In 2010/11, variety Diamant had more rotted tubers than Nicola.

At 12 WAS, irrigation interval of 3 days recorded significantly higher percent rotted tubers than 9 days interval in 2009/10 dry season. There was no significant irrigation effect on percent rotted tubers in 2010/11, 2011/12 and the combined data as presented in Table 2. Application of fertilizer did not show significant effect on percent rotted tubers in all seasons and the combined data. Varieties Bertita and Diamant produced significantly higher rotted tubers than Nicola in 2009/10. In 2010/11, Diamant rotted more than both Bertita and Nicola, which were at par. In 2011/12 and the combined data, Diamant had more rotted tubers than Bertita; and Bertita than Nicola.

At 16 WAS, irrigation at 3 days interval recorded significantly higher rotted tubers than 9 days in the 2009/10 dry season (Table 2). In 2010/11 and 2011/12 seasons, irrigation treatment had no significant effect on percent rotted tubers. In the combined data, there were more rotten tubers with 3 days irrigation intervals than with 9 days interval. NPK rate did not show significant effect on percent rotted tubers in all seasons and the combined. Varieties Bertita and Diamant had similar percent rotted tubers, and each was significantly higher compared with Nicola in all seasons and the combined data. Interactions of irrigation intervals, NPK rates and variety on percent rotted tuber at all assessment periods were not significant in all trials and the combined data.

Percent Tuber Weight Loss

At 4 WAS, irrigation interval and NPK rate did not show significant effect on tuber weight loss after 4 weeks of storage in all the seasons and the combined data as shown in Table 3. Bertita and Diamant recorded a significantly higher tuber weight loss than Nicola in

2010/11, 2011/12 and the combined data; but in 2009/10, variety did not affect tuber weight loss after 4 weeks of storage.

At 8 WAS, irrigation interval and NPK rate did not show significant effect on tuber weight loss after 8 weeks of storage in all the seasons and the combined as shown in Table 3. Variety Diamant recorded higher percent weight loss at 8 WAS than Bertita and Nicola in 2009/10 season. Variety did not influence tuber weight loss in 2010/11season; but in 2011/12 and the combined, varieties Diamant and Bertita were at par, and both recorded significantly higher tuber weight loss than variety Nicola.

At 12 WAS, irrigation interval did not show significant effect on percent tuber weight loss in all the seasons and the combined data as shown in Table 4. Percent tuber weight loss was affected by the application of NPK fertilizer in 2011/12 dry season. In this case, NPK at 900 kg ha^{-1} caused significant percent weight loss than 300 kg NPK ha^{-1}. Variety Diamant recorded higher tuber weight loss than Bertita and the least was in Nicola during 2009/10 season. In 2010/11, 2011/12 and the combined, varieties Diamant and Bertita lost more weight than Nicola after 12 weeks of storage.

At 16WAS, irrigation interval and NPK fertilization did not show significant influence on percent tuber weight loss in all the seasons and the combined as shown in Table 4. Diamant and Bertita resulted in greater tuber weight loss than Nicola in all seasons and the combined after 16 weeks of storage. Interactions of irrigation intervals, NPK rates and variety on percent tuber weight loss at all assessment periods were not significant in all trials and the combined data.

Percent Sprouted Tubers

At 4 WAS, irrigation interval and NPK rate did not affect percent sprouted tubers in all the seasons and combined as shown in Table 5. Variety Bertita recorded significantly higher percent sprouted tubers than variety Diamant, which was in turn higher than variety Nicola in 2009/10 dry season. In 2010/11 and 2011/12 dry seasons, variety Diamant recorded significantly higher percent sprouted tubers than variety Bertita, which was in turn higher than variety Nicola. In the combined data however, both varieties Bertita and Diamant were at par, and recorded significantly higher percent sprouted tubers than variety Nicola.

At 8 WAS, irrigation interval and NPK fertilizer rate did not affect percent sprouted tubers in all the seasons and the combined as shown in Table 5. However, variety Bertita recorded significantly higher percent sprouted tubers than variety Diamant, which was in turn significantly higher than Nicola in 2009/10 and 2010/11 dry seasons. In 2011/12 and the combined mean, Bertita and Diamant were at par, and recorded significantly higher percent sprouted tubers than variety Nicola. Interactions of irrigation intervals, NPK rates and variety on percent sprouted tuber at all assessment periods were not significant in all trials and the combined data.

IV. Discussion

Storability defined as the ability of potato tuber to remain practically edible and marketable over a relatively long period of time with minimum losses; is a function of tuber dormancy, respiration rate, evaporation and infection by micro-organisms. These factors are greatly influenced by temperature, relative humidity and genotype [7]. The high percent rotted tubers observed in variety Bertita could be attributed to the higher tuber nitrogen content of this variety than Nicola, which encouraged microbial activities in the former than the latter variety [11]. It could also be due to inherent genetic characteristics which might have slowed rotting of tubers in Nicola than the other varieties [12]. The earlier and higher percent sprouting of varieties Bertita and Diamant compared with variety Nicola is an indication that the latter is inherently a longer dormancy crop compared with the other two varieties. It has been reported that water loss (evaporation) from potato skin, sprout and wound is in the ratio of 1:100:300 [13]. As a result, potato tubers that sprout earlier and in large numbers are bound to lose more weight (in the case of Bertita and Diamant) compared to those that sprout later and in small numbers as was the case with Nicola. Researchers [9] [13] [14] had identified tuber sprouting in potato as the main indicator of dormancy breakage and that variety Nicola [13] is among the longer dormancy crop which possesses the potential to store up to 5 months without substantial weight loss. It appeared that irrigation interval and fertilizer rates did not show significant effect on total tuber weight loss; and even with the significant effect of variety, the weight loss was generally in the range of 40 - 48% (Tables 3 and 4) within 8 weeks of storage. This value is comparable to weight loss of 40 - 50% obtained in the Jos plateau over a storage period of 24 weeks [13]. The major reason for the higher storage loses recorded in the study area was probably due to high evaporation caused by high ambient temperatures and relative humidity (Appendix I) that prevailed during the period of storage (February-June) as opined by [4].

V. Conclusion and Recommendation

From the result of this study, NPK rates up to 900 kg ha^{-1} did not affect potato storability. Frequent irrigation of 3 days interval increased potato spoilage during storage. Potato variety Nicola was the least rotted with less weight loss and late sprouted during the four months storage period. Therefore, variety Nicola could be recommended for production in the study area due to its post-harvest storability.

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Table 1. Effect of irrigation interval and NPK rates on percent rotted tubers at 4 and 8 WAS of three potato varieties in 2009-12 dry seasons and the combined data at Jega

Treatments	4 WAS				8 WAS			
	2009/10	2010/11	2011/12	Combined	2009/10	2010/11	2011/12	Combined
Variety								
Bertita	7.43ab	5.52a	8.19	7.05a	19.78a	8.84ab	14.03	14.22a
Diamant	9.90a	4.01ab	7.69	7.20a	22.02a	11.21a	14.12	15.78a
Nicola	5.55b	2.61b	6.15	4.77b	16.57b	5.73b	11.92	11.41b
SE±	**0.950**	**1.110**	**1.030**	**0.940**	**1.050**	**1.490**	**1.290**	**1.180**
Irrigation (days)								
3	9.41a	4.47	8.24	7.37a	22.27a	7.94	14.55	14.92
6	7.24ab	4.43	7.12	6.26ab	18.49ab	9.96	13.51	13.99
9	6.22b	3.25	6.67	5.39b	17.61b	7.89	12.02	12.50
SE±	**0.994**	**1.331**	**1.521**	**1.355**	**1.330**	**1.896**	**1.938**	**1.692**
NPK rates (kg ha^{-1})								
0	7.14	3.33	6.96	5.81	18.42	7.97	12.77	13.05
300	6.54	5.12	8.87	6.85	19.41	10.58	15.21	15.07
600	8.67	2.97	6.04	5.90	19.37	8.23	11.49	13.03
900	8.15	4.77	7.52	6.81	20.61	7.61	13.96	14.06
SE±	**1.147**	**1.536**	**1.755**	**1.563**	**1.535**	**2.188**	**2.237**	**1.952**
Interactions	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column in each treatment are not significantly different at 5% using DMRT. NS= not significant. WAS= Weeks after storage.

Table 2. Effect of irrigation interval and NPK rates on percent rotted tubers at 12 and 16 WAS of three potato varieties in 2009-12 dry seasons and the combined data at Jega

Treatments	12 WAS				16 WAS			
	2009/10	2010/11	2011/12	Combined	2009/10	2010/11	2011/12	Combined
Variety								
Bertita	40.30a	21.89b	31.95b	31.38b	52.64a	52.30a	62.25a	55.73a
Diamant	41.19a	27.33a	38.78a	35.76a	55.31a	55.49a	69.00a	59.93a
Nicola	30.10b	21.00b	21.92c	24.34c	39.12b	42.53b	45.57b	42.41b
SE±	**1.690**	**2.010**	**2.080**	**1.890**	**2.230**	**2.510**	**2.900**	**2.360**
Irrigation (days)								
3	41.55a	21.24	31.7	31.49	54.40a	49.34	63.80	55.85a
6	35.36ab	26.99	31.53	31.39	46.61b	53.67	58.50	52.93ab
9	34.68b	21.98	29.44	28.70	46.06b	47.30	54.52	49.29b
SE±	**2.218**	**3.366**	**3.688**	**2.583**	**2.889**	**3.358**	**3.785**	**3.086**
NPK rates (kg ha^{-1})								
0	35.35	21.77	28.84	28.65	46.63	46.41	58.53	50.52
300	38.72	23.62	31.32	31.22	51.59	53.14	59.82	54.85
600	35.42	22.89	28.61	28.97	46.12	49.46	54.71	50.09
900	39.30	25.35	34.74	33.14	51.76	51.40	62.70	55.29
SE±	**2.559**	**3.883**	**4.255**	**2.980**	**3.333**	**3.875**	**4.367**	**3.560**
Interactions	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column in each treatment are not significantly different at 5% using DMRT. NS= not significant. WAS= Weeks after storage.

Table 3. Effect of irrigation interval and NPK rates on percent tuber weight loss at 4 and 8 WAS of three potato varieties in 2009-12 dry seasons and the combined data at Jega

Treatments	4 WAS				8 WAS			
	2009/10	2010/11	2011/12	Combined	2009/10	2010/11	2011/12	Combined
Variety								
Bertita	25.70	24.50a	27.57a	25.92a	55.66a	40.16	48.26a	48.02a
Diamant	25.25	16.28b	21.14b	20.89b	57.81a	40.26	48.59a	48.88a

Nicola	24.69	17.26b	21.05b	21.00b	38.90b	34.32	32.15b	35.12b
SE±	**1.760**	**2.240**	**1.350**	**1.900**	**2.120**	**2.430**	**2.130**	**2.190**
Irrigation (days)								
3	23.57	17.75	22.19	21.17	48.83	37.32	42.48	42.88
6	23.64	22.03	23.02	22.90	49.79	40.77	43.74	44.77
9	28.43	18.26	24.55	23.75	53.75	36.66	42.74	41.38
SE±	**2.263**	**2.480**	**2.235**	**2.701**	**2.698**	**3.099**	**3.220**	**3.092**
NPK rates (kg ha^{-1})								
0	27.70	21.30	22.94	23.98	54.49	37.13	40.18	43.94
300	24.18	17.19	22.07	21.15	46.09	40.39	45.45	43.98
600	20.92	20.38	24.65	21.98	51.34	38.86	44.31	44.84
900	28.06	18.52	23.34	23.31	51.23	36.61	42.01	43.28
SE±	**2.611**	**2.861**	**2.579**	**3.116**	**3.113**	**3.576**	**3.715**	**3.568**
Interactions	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column in each treatment are not significantly different at 5% using DMRT. NS= not significant. WAS= Weeks after storage.

Table 4. Effect of irrigation interval and NPK rates on percent tuber weight loss at 12 and 16 WAS of three potato varieties in 2009-12 dry seasons and the combined data at Jega

Treatments	12 WAS				16 WAS			
	2009/10	2010/11	2011/12	Combined	2009/10	2010/11	2011/12	Combined
Variety								
Bertita	88.45b	65.17a	68.29a	73.97a	94.10a	88.15a	98.85a	93.70a
Diamant	91.53a	67.53a	70.29a	76.45a	92.58a	87.83a	97.43a	92.61a
Nicola	56.75c	43.65b	50.17b	50.19c	75.13b	60.31b	74.23b	69.89b
SE±	**1.480**	**2.320**	**3.270**	**2.540**	**1.210**	**1.860**	**1.170**	**1.440**
Irrigation (days)								
3	79.00	55.33	61.32	65.28	88.47	76.53	89.78	84.93
6	78.97	63.10	65.48	69.18	87.80	80.66	89.74	85.33
9	78.76	57.72	61.95	66.14	85.58	79.10	90.59	85.96
SE±	**2. 052**	**3.384**	**3.673**	**2.303**	**1.568**	**2.938**	**2.063**	**1.869**
NPK rates (kg ha^{-1})								
0	81.28	57.88	61.78ab	66.98	89.31	79.48	90.92	86.57
300	78.10	59.41	55.29b	64.27	86.73	80.66	90.95	86.11
600	79.18	58.20	65.60ab	67.66	87.79	77.76	88.92	84.82
900	77.09	59.64	69.01a	68.58	83.32	77.16	89.89	84.12
SE±	**2.368**	**3.905**	**4.238**	**2.657**	**1.803**	**3.931**	**2.830**	**2.146**
Interactions	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column in each treatment are not significantly different at 5% using DMRT. NS= not significant. WAS= Weeks after storage.

Table 5. Effects of irrigation interval and NPK rates on percent sprouted tubers at 4 and 8 WAS of three potato varieties in 2009-12 dry seasons and the combined data at Jega

Treatments	4 WAS				8 WAS			
	2009/10	2010/11	2011/12	Combined	2009/10	2010/11	2011/12	Combined
Variety								
Bertita	49.79a	56.22b	64.33b	56.78a	98.18a	99.20a	99.21a	98.86a
Diamant	35.69b	68.69a	71.91a	58.76a	94.75b	95.69b	97.44a	95.96a
Nicola	7.64c	28.49c	32.03c	22.72b	67.71c	66.98c	62.68b	65.79b
SE±	**4.060**	**2.600**	**2.160**	**2.460**	**1.20**	**1.16**	**1.02**	**0.98**
Irrigation (days)								
3	27.46	46.93	51.12	42.10	86.90	87.50	86.53	86.98
6	36.68	52.29	58.73	49.23	86.15	88.42	84.57	86.38
9	28.98	54.18	58.42	47.19	87.59	87.95	88.24	87.93

SE±	**4.113**	**4.153**	**3.989**	**3.060**	**1.380**	**1.860**	**1.180**	**1.14**
NPK rates (kg ha^{-1})								
0	33.13	48.57	54.25	45.32	84.18	88.82	85.42	86.14
300	32.29	51.80	56.09	46.73	87.32	90.04	88.25	88.54
600	31.30	51.71	57.03	46.68	87.23	86.85	86.17	86.75
900	27.24	52.44	56.99	45.62	88.79	86.11	85.94	86.95
SE±	**4.747**	**4.796**	**4.600**	**3.530**	**1.592**	**2.146**	**1.361**	**1.315**
Interactions	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column in each treatment are not significantly different at 5% using DMRT. NS= not significant. WAS= Weeks after storage.

Appendix I: Mean monthly temperatures and relative humidity at the experimental site during the period of the experiments (2009-2012)

Month	Temperature (^{O}C)				Relative Humidity (%)			
	2009	2010	2011	2012	2009	2010	2011	2012
January	-	23.8	25.8	23.4	-	27	25	24
February	-	26.0	27.3	25.8	-	23	22	20
March	-	30.8	30.7	31.7	-	22	22	20
April	-	35.0	35.6	34.9	-	33	38	30
May	-	33.2	33.9	34.2	-	39	35	38
June	-	28.2	30.4	31.4	-	52	55	60
July	-	27.2	26.8	-	-	70	68	-
August	-	27.2	26.7	-	-	79	80	-
September	-	26.8	25.2	-	-	78	81	-
October	29.2	26.7	28.6	-	47	62	69	-
November	29.4	28.4	29.6	-	29	30	27	-
December	26.9	25.3	25.8	-	27	26	25	-

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Author's Profile

Dr. Adamu Muhammad was born 43 years ago in Birnin Kebbi, Kebbi State, Nigeria. He obtained his B. Agriculture and M. Sc. Crop Science in Usmanu Danfodiyo University, Sokoto, Nigeria. He completed his PhD in Agronomy at the Ahmadu Bello University, Zaria, Nigeria. He is currently the Head of Department of Crop Science, Deputy Dean of the Postgraduate School and Director of Examinations and Registration of the Kebbi state University of Science and Technology, Aliero, Nigeria. He has published more than 30 papers in reputed journals nationally and internationally

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