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RESEARCH ARTICLE

Fertilization of NPK boosts the yield and quality of date palm(*Phoenix sylvestris Roxb.*) juice under subtropical conditions

Md. Sohrab Hossain[1], Najrul Islam[2], Muhammad Salim[2], Md. Moshiur Rahman[2], Md. Romij Uddin[2] and Swapan Kumar Paul[2,*]

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Abstract

An experiment was conducted to assess the effects of NPK fertilizers on juice and goor (brown sugar) yield and juice quality of date palm (*Phoenix sylvestris Roxb*.).

The trial examined N, P, and K fertilizers consisting of each of three levels Firstly, in (2013-2014) three levels of N viz. 0, 600, 1200 g/plant, and three levels of P viz. 0, 100, 200 g/plant, and three levels of K viz. 0, 700, 1400 g/plant. Secondly, in (2014-2015), four N levels viz. 0, 600, 1200, 1800 g/plant, and four levels of P viz. 0, 100, 200, 300 g/plant, and two levels of K viz. 0 and 1400 g/plant) and assigned in a factorial RCBD with three replications. Based on the results of the first year of experimentation, the experiment was repeated in the following year by including one more level each of N and P, and dropping one level of K as followed in the trial.

The data collection was made on juice and goor yields as obtained from individual plants throughout the tapping period. As quality parameters brix (%), Pol (pure sucrose in juice) (%), purity, and reducing sugar (RS) of juice were determined at the same period every week.

The results revealed that applications of NPK fertilizers significantly impacted different parameters under study. N and K had more pronounced effects than P concerning yield and qualitative parameters among the nutrient elements.

The highest juice yield was harvested by applying the combination of NPK at 1800g, 300g, and 1400g/plant but the highest goor yield was processed from the NPK combination of 1200g, 200g, and 1400g/plant due to obtaining higher brix reading.

Having the highest values each of goor (*jaggary*) yield, gross return, gross margin, and BCR with less variable cost, the application of NPK fertilizers at 1200g, 200g, and 1400g/per plant could be considered as the best doses for successful date palm cultivation for tapping purposes.

Keywords: Nutrient; Reducing sugar; Goor; *Jaggary*; Sugar recovery; BCR**.**

Introduction

Sugar is an essential human food item for proper brain functioning and development. The Food and Agriculture Organization recommends consuming 13 kg of sugar for a person annually in case of balanced nutrition (FAO. 1982).

According to the American Heart Association (AHA), the maximum quantity of daily added sugars should be 37.5g or 9 teaspoons (150 calories) for men and 25g or 6 teaspoons (100 calories) for women (Kris Gunnars, 2015).

As such for 163 million people, the present requirement of sugar in Bangladesh is about 2.13 million tons. However, the current internal production of sugar is about 0.13 million tons and goor ((*jaggary*) 0.34 million tons (0.31 million tons from sugarcane and 0.03 million tons from palm juice) (BBS, 2013; BSRI, 2014; Rahman et al., 2016; Paul et al., 2019). So, the country has a deficit of about 1.66 million tons of sugar or goor (*jaggary*).

In this situation, the country's sugar or goor requirement is met by importing refined or raw sugar from abroad by spending a huge amount of hard-earned foreign currency (Paul et al., 2018a; Paul et al., 2018b).

Both sugar and goor (*jaggary*) are processed from sugarcane in Bangladesh but being a long-duration crop it fetches less benefit as compared to other profitable short-duration crops (Sarker et al., 2018; Bithy et al., 2020).

Such short-duration crops gradually replaced sugarcane in low-lying marginal and char lands. In this situation, there is little opportunity to upsurge both cane area and production of sugarcane to meet the higher demand for sugar or goor (*jaggary*) for the ever-increasing population (Rahman et al., 2016).

Therefore, the country has to adopt diversification of sugar production from sources other than sugarcane such as the plantation of allied sugar crops like date palm, palmyra palm, sugarbeet, sweet corn, golpata etc. for mitigating the demand.

[1] Bangladesh Sugarcrop Research Institute, Regional Station, Thakurgaon, Bangladesh

[2] Department of Agronomy, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

[*]**Correspondence authors:** skpaul@bau.edu.bd

These would increase the production of sugar and goor (*jaggary*) and also increase the income of the rural people. Among the allied sugar crops, date palm (*Phoenix sylvestris Roxb.)* is a vital food cum cottage industrial plant in Bangladesh and is grown with no inputs and minimum care. These plants can be tapped at the age of 5 years and may be continued for more than twenty years (Abedin et al., 1987).

In Bangladesh, date palm is a common plant species and grows in homesteads, roadsides, embankment sides, marginal lands, fallow lands, and orchards or cropland boundaries in an unplanned way.

Date palm is grown in around 5360 acres of land and the total estimated juice production is 2.4 million tons @ 12.5 percent goor (*jaggary*) recovery with a production of 30000 tons of goor (*jaggary*) yearly (BBS, 2013).

Although there are enormous scopes of growing these trees and these may produce million tons of juice and goor (*jaggary*) as well as generate employment and reduce poverty level but economic potential of this tree is mostly unknown to people and remains unattended. Growers have inadequate technical knowledge regarding the modern method of cultivation.

They never apply any fertilizer and adopt other management practices to achieve higher yields. Fertilization management is one of the major practices in crop production worldwide. In this concern, nutrients deficiency is a crucial factor that dramatically declines crop yield and quality (Ramadan et al., 2023).

The edaphic circumstances are regarded as the most critical agent affecting the availability and uptake of nutrients (Ali et al., 2024). It has been reported that soil salinity (Lasheen et al., 2024), soil acidity (Abd El-Mageed et al., 2022), and soil moisture content (Salem et al., 2022) are the most edaphic factors relating to nutrients availability.

However, insufficient availability of nutrients could be compensated by exogenous supply, hence sustaining the production of the plantations (Elgala et al., 2022).

Nitrogen is the most significant element that determines the appropriate growth for crop productivity since it has the potential to act in various metabolisms (Saudy et al. 2020a).

Nitrogen fertilizers improved the plant pigments and florescence of chlorophyll (Abou El-Enin et al., 2023), furthermore, nitrogen fertilizers enhanced the ability of plants to withstand the stresses (Saudy and El-Metwally 2023). Accordingly, growth and yield positively correlated with nitrogen applications (Saudy et al., 2018).

On the other hand phosphorus (Saudy et al. 2020b) and potassium (Rizk et al., 2023) had substantial influences on enhancing plant growth and productivity under normal of adverse conditions. N, P, and K fertilization influence date palm growth and productivity (Abou Sayed-Ahmed et al., 2005; El-merghany et al., 2016).

Application of 0.40 kg N/tree was the best and P and K together increased palm yield. Soliman and Osman (2003) studied the effect of N and K application to Samany date palm.

Organic fertilization in date palm farms is very important to improve soil structure which reduces elements and produce clean fruits (El-merghany et al., 2016).

However, chemical and organic fertilization plays an important role in crops yield and quality improvement (Zivdar et al., 2016; Tohidloo et al., 2018; Paul et al., 2020; Serri et al., 2021).

Even, no systematic research work so far has been done on some important agronomic management practices for having improved yield and quality juice production.

Considering the above facts, the study was undertaken to develop a package with fertilization of date palm plants for the production of both quality juice and goor (*jaggary*).

Materials and methods

The experiment was conducted at Bangladesh Sugarcrop Research Institute (BSRI) Farm, Ishurdi, Pabna under the Agro-Ecological Zone of the High Ganges River Floodplain of Bangladesh (AEZ 11).

The site is a calcareous high land soil having good drainage system and sandy loam in texture (sand 67%, silt 22% and clay 11%) with high pH (7.51), Organic matter 7.51%, Total nitrogen 0.06%, Calcium 11.51 meq/100g, Magnesium 0.83 meq/100g, Potassium 0.13 meq/100g, Phosphorus 7.50 µg/g, Sulphur 22.00 µg/g, Boron 0.20 µg/g, Iron 3.40 µg/g and Zinc 0.85 µg/g.

The experimental area is under the sub-tropical climate. Theclimatic data at the experimental site during experimentation are presented in Figure 1.

The experiment was laid out in a factorial randomized complete block design with three replications where a single plant was considered as a replication for each treatment. The trees were taken almost of similar age, height, girth, vigor and juice-yielding performance depending on the previous year's observations.

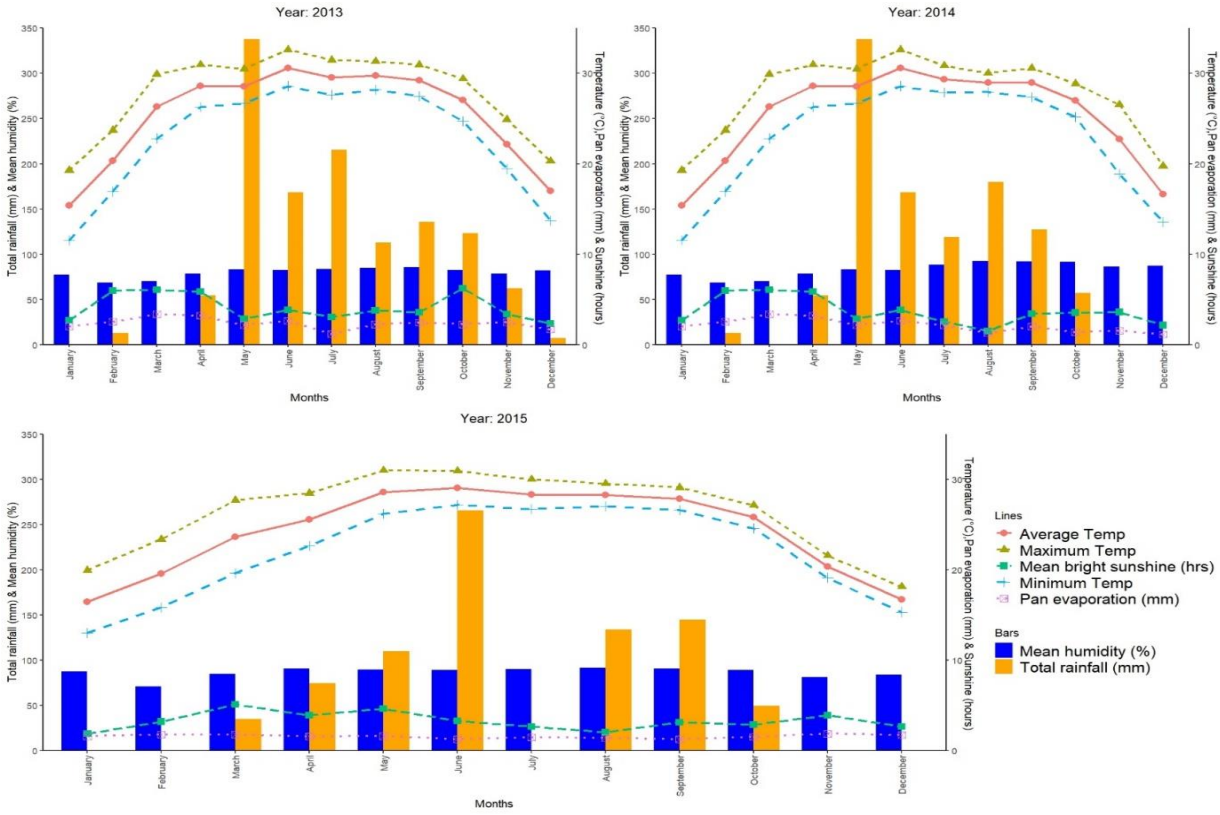

Figure 1. Weather conditions in the study periods.

In the (2013-2014) tapping season each of three levels of N (0, 600, 1200g/plant) from urea, P (0, 100, 200g/plant) from triple super phosphate and K (0, 700, 1400g/plant) from muriate of potash fertilizers were combined and applied to the plants.

The whole amount of P and one-third of N and K fertilizers were applied on the 1st week of September 2013 and the remaining two-thirds of N and K fertilizers were applied in two equal splits at 30-day intervals in the spaded one meter circle area around each tree base and then mixed with soil. Light irrigation was applied just after fertilization.

The experiment was repeated in the (2014-2015) tapping season with a modified form depending on the results of the first year experimentation where one more level each of N (1800g/plant) and P (300g/plant) were included and one level of K (700g/plant) was dropped.

For the (2013-2014) tapping season- three levels of nitrogen viz. 0 g/plant (N_0), 600 g/plant (N_1), 1200 g/plant (N_2), and three levels of phosphorus viz. 0 g/plant (P_0), 100 g/plant (P_1), 200 g /plant (P_2), and three levels of potassium viz. 0 g/plant (K_0), 700 g/plant (K_1), 1400 g/plant (K_2).

For (2014-2015) tapping season- four nitrogen levels viz. 0 g/plant (N_0), 600 g/plant (N_1), 1200 g/plant (N_2), 1800 g/plant (N_3), and four levels of phosphorus viz. 0 g/plant (P_0), 100 g/plant (P_1), 200 g/plant (P_2), 300 g/plant (P_3), and two levels of potassium viz. 0 g/plant (K_0), 1400 g/plant (K_1)

Daily juice production from each plant was weighed and recorded separately starting from 15 November 2013 and 2014, respectively which was continued up to the end of the tapping season and during the same period goor was prepared from collected juice and goor yield was recorded accordingly.

Chemical analysis of date palm juice for brix (%), Pol (%), purity (%) and Reducing Sugar (RS) (%) was done throughout the tapping period where sampling was conducted once a week early in the morning. Brix (%) was measured in the juice of fresh roots by using a Hand Refractometer (ATAGO, Japan) or Brix meter. Pol (%) or Sucrose (%) was determined in fresh samples of date palm juice polarimetericallly by using an automatic Polarimeter (Model: ATAGO AP-300) standardized at 20^0C by Horne's dry lead method at physiology and sugar chemistry division of BSRI, Ishurdi, Bangladesh.

Purity percentage was determined as a ratio between sucrose % and Brix (%) or total soluble solids % (TSS) of juice. Reducing sugar was calculated by the usual formula: RS % of juice = × Where, F.F. = Fehling factor and T.V. = Titre value.

The economics of fertilization for date palm juice and goor production were calculated in terms of total variable cost, gross return, gross margin and benefit-cost ratio. Gross return was calculated by multiplying the total volume of output by the average unit price in the harvesting period and net return was calculated by deducting all costs from the gross return.

The collected data were analyzed using the ANOVA technique. The mean comparison was made through the computer-based statistical analysis by the computer package Statistix 10 program for the Windows Version (Statistix-10, 2013). The differences among treatment means were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results

From the experimental results, it was observed that the juice and goor (jaggary) yield of date palm were influenced significantly by the application of different levels of N fertilizer applied both the tapping (juice collection) seasons of (2013-14 and 2014-15) (Table 1 & Figure 2). In (2013-14) season the maximum amount of juice and goor yield of 95.92 l/plant and 10.84 kg/plant, respectively were harvested at the level of N_2 where individual plants received 1200g N followed by N_1 (600g N/plant). In the (2014-15) season the highest juice yield was harvested from N_3 (1800 g/plant) level produced 96.91 l/plant which was statistically identical with N_2 (1200 g/plant) and the highest goor yield of 11.53 kg/plant was produced in N_2 (1200 g/plant) which was closely followed by N_3 level and the lowest yields were obtained from the control plants in both the seasons. The result showed that as juice yield increased with increasing of N level, goor yield increased sharply up to N_2 level but after that, the rate declined though having the higher juice yield (Figure 2).

Table 1. Effects of N, P and K fertilizers on juice & *goor* yield; brix, pol, purity and RS content of date palm juice (2013-2014).

Level of NPK	Juice yield (l/plant)	*Goor* yield (kg/plant)	Brix (%)	Pol (%)	Purity (%)	RS (%)
N_0	48.13 c	6.26 c	13.18 a	11.72 a	89.12 c	0.55 a
N_1	66.47 b	8.36 b	12.78 a	11.54 a	90.22 b	0.48 b
N_2	95.92 a	10.84 a	11.53 b	10.48 b	90.81 a	0.41 c
CV (%)	9.83	6.80	8.20	8.41	0.08	8.13
LSD (0.05)	3.76	0.31	0.55	0.51	0.04	0.02
Level of significance	**	**	**	**	**	**
P_0	60.00 c	7.39 c	12.72	11.09	87.18 c	0.51 a
P_1	69.80 b	8.42 b	12.46	11.32	90.85 b	0.47 b
P_2	80.77 a	9.66 a	12.32	11.18	90.96 a	0.46 b
CV (%)	9.83	6.80	8.20	8.41	0.08	8.13
LSD (0.05)	3.76	0.31	0.55	0.51	0.04	0.02
Level of significance	**	**	NS	NS	**	**
K_0	52.75 c	6.87 c	13.15 a	11.71 a	89.25 c	0.54 a
K_1	73.64 b	8.85 b	12.48 b	11.27 a	90.30 b	0.48 b
K_2	84.18 a	9.74 a	11.87 c	10.74 b	90.48 a	0.41 c
CV (%)	9.83	6.80	8.20	8.41	0.08	8.13
LSD (0.05)	3.76	0.31	0.55	0.51	0.04	0.02
Level of significance	**	**	**	**	**	**

Figures in a column having different letters differ significantly at 5% level of probability; ** = Significant at p≤0.01 and NS = Not Significant.

Table 2. Effects of N, P and K fertilizers on brix, pol, purity and RS content of date palm juice (2014-2015).

Level of NPK	Brix (%)	Pol (%)	Purity (%)	RS (%)
N_0	14.15 a	12.52 a	88.49 c	0.63 a
N_1	13.24 b	11.87 b	89.62 b	0.53 b
N_2	12.50 c	11.27 c	90.16 a	0.45 d
N_3	11.85 d	10.68 d	90.12 a	0.48 c
CV (%)	6.36	6.34	0.07	6.50
LSD (0.05)	0.47	0.42	0.04	0.02
Level of significance	**	**	**	**
P_0	13.37 a	11.90 a	89.04 d	0.57 a
P_1	13.02 ab	11.64 ab	89.34 c	0.54 b
P_2	12.86 bc	11.52 ab	89.58 b	0.52 c
P_3	12.50 c	11.28 b	90.24 a	0.47 d
CV (%)	6.36	6.34	0.07	6.50
LSD (0.05)	0.47	0.42	0.04	0.02
Level of significance	**	*	**	**
K_0	13.42 a	11.90 a	88.66 b	0.59 a
K_1	12.45 b	11.27 b	90.52 a	0.46 b
CV (%)	6.36	6.30	0.07	6.46
LSD (0.05)	0.33	0.30	0.03	0.01
Level of significance	**	**	**	**

Figures in a column having different letters differ significantly at 5% level of probability; ** = Significant at p≤0.01, * = Significant at p≤0.05 and NS = Not Significant.

Significant variations were observed in brix reading, pol (%), purity (%) and RS (%) of date palm juice by the application of different levels of N fertilizer in both seasons (Table 1 and 2).

The highest brix, pol and RS readings were found in N0 level and the lowest values were recorded in the top levels of N each year. It was observed that except purity (%); brix reading, pol and RS contents seemed to be negatively correlated with juice yield for N fertilization.

With the increase of the N level juice yield increased sharply up to N_2 level and brix values went downward gradually. As a result, though total goor yield was rising up having increased juice yield, a diminishing trend was noted after N_2 level (Figure 2).

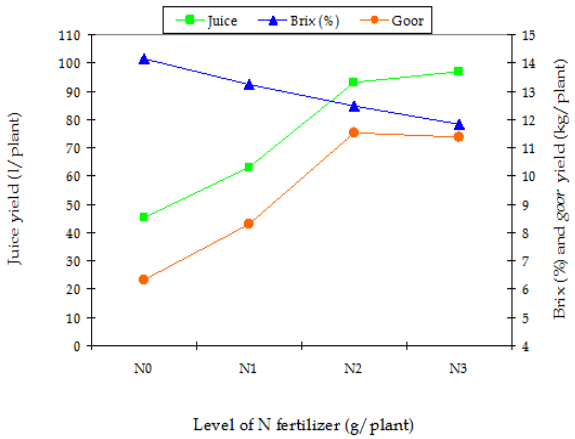

Figure 2. Effects of N on juice yield, brix and goor (jaggary)yield of date palm (2014-15).

Different levels of P created significant variations in juice and goor yields of date palms in the tapping seasons of (2013-14 and 2014-15) (Table 1and Figure 3).

From the results it was identified that juice and goor yield increased with the increasing of P level and the highest yields were obtained with the highest levels of P each year.

In the (2014-15) tapping year, the highest juice yield of 82.11 l/plant was collected from P_3 (300 g/plant) followed by 79.68 l/plant in P_2 (200 g/plant) but this difference was statistically identical.

An almost similar amount of goor was produced from P_2 and P_3 levels and it was observed that juice and goor yield increased gradually up to P_2 level, after that it increased at a slower rate (Figure 3).

Brix and pol readings were not affected significantly for applying different levels of P fertilizer but purity(%) and reducing sugar (RS) content were affected in the tapping season (2013-14), whereas all the parameters were affected significantly in the tapping season of (2014-15) (Table 1 and Table 2).

With the increment of P level, brix, Pol and RS content decreased but having higher juice yield, goor yield increased up to P_2 level with a declining trend and thereafter, it decreased for further progress of P level (Figure 3). Purity (%) was maximum with the top levels of P in both seasons.

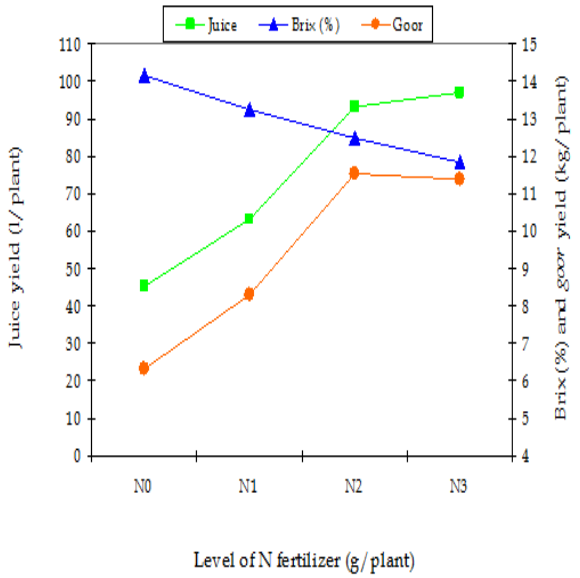

Figure 2. Effects of N on juice yield, brix and *goor* (*jaggary*) yield of date palm (2014-15).

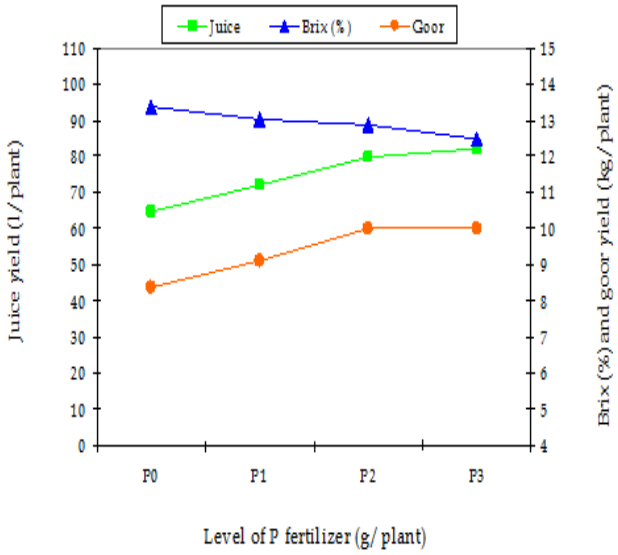

Figure 3. Effects of P on juice yield, brix, and goor (jaggary) yield of date palm (2014-15).

Different levels of P created significant variations in juice and goor yields of date palms in the tapping seasons of (2013-14) and (2014-15) (Table 1 and Figure 3).

From the results it was identified that juice and goor yield increased with the increasing of P level and the highest yields were obtained with the highest levels of P each year.

In the (2014-15) tapping year, the highest juice yield of 82.11 l/plant was collected from P_3 (300 g/plant) followed by 79.68 l/plant in P_2 (200 g/plant) but this difference was statistically identical.

An almost similar amount of goor was produced from P_2 and P_3 levels and it was observed that juice and goor yield increased gradually up to P2 level, after that it increased at a slower rate (Figure 3).

Brix and pol readings were not affected significantly for applying different levels of P fertilizer but purity(%) and reducing sugar (RS) content were affected in the tapping season (2013-14), whereas all the parameters were affected significantly in the tapping season of (2014-15) (Table 1 and Table 2).

With the increment of P level, brix, Pol and RS content decreased but having higher juice yield, goor yield increased up to P_2 level with a declining trend and thereafter, it decreased for further progress of P level (Figure 3). Purity (%) was maximum with the top levels of P in both seasons.

Responses of K fertilizer on juice and goor yields of date palm were significant in both the years of experimentation and the top level of K (1400g/plant) produced the highest juice and goor yields (Table 1 and Figure 4).

The graph of the two K levels in (2014-15) showed that juice yield increased sharply when the date plant received K fertilizer. Brix (%), Pol (%), purity (%), and RS content were influenced significantly by different K levels in both seasons.

It was monitored that for increasing K level, brix, Pol, and RS contents went downward but having higher juice yield consisting of higher purity (%), total goor production increased.

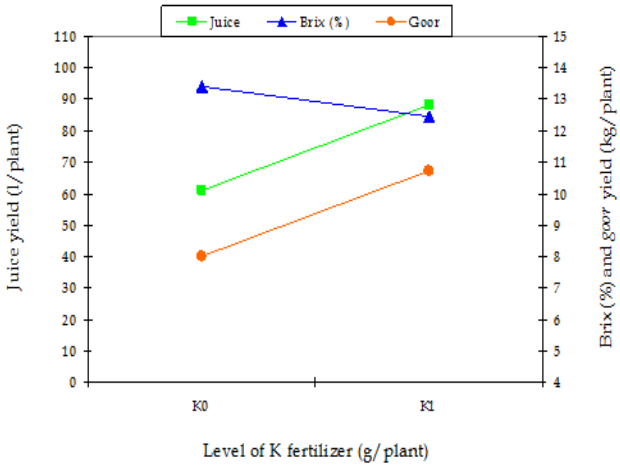

Figure 4. Effects of K on juice yield, brix and *goor* (*jaggary*) yield of date palm (2014-15).

Significant variations were observed in juice and goor yields of date palm in both the tapping seasons of (2013-14) and (2014-15) due to the combined use of N, P and K fertilizers (Table 3 and Figure 5). In the season of (2013-14), a combination of $N_2 \times P_2 \times K_2$ (1200g/plant N, 200g/plant P, and 1400g/plant K) produced the highest juice and goor yield of 132.96 l/plant and 14.08 kg/plant, respectively. In (2014-15), the highest juice yield of 128.74 l/plant was harvested from the combination of $N_3 \times P_3 \times K_1$ (1800g/plant N, 300g/plant P and 1400g/plant K) which was statistically at par with 122.95 l/plant obtained from the combination of $N_2 \acute{} P_2 \acute{} K_1$ (1200g/plant N, 200g/plant P and 1400g/plant K) from which the highest amount of goor (14.76 kg/plant) was prepared due to having higher brix reading.

The pattern of the graph also illustrated that goor yield obtained for PK fertilization increased when N fertilizer was added with that and a significant increasing trend was observed for the increasing of N doses and it was up to N_2 level (Figure 5).

Table 3. Interaction effects of N, P and K fertilizers on brix, pol, purity and RS content of date palm juice (2013-2014).

Interaction (N × P × K)	Juice yield (l/plant)	*Goor* yield (kg/plant)	Brix (%)	Pol (%)	Purity (%)	RS (%)
$N_0 \times P_0 \times K_0$	34.16 n	5.19 m	13.99 a	12.20 abc	87.18 s	0.69 a
$N_0 \times P_0 \times K_1$	43.56 mn	6.30 klm	13.86 ab	12.23 ab	88.19 r	0.63 ab
$N_0 \times P_0 \times K_2$	37.77 mn	5.66 lm	12.15 c-j	11.06 a-g	91.03 de	0.42 jkl
$N_0 \times P_1 \times K_0$	48.28 klm	6.46 j-m	13.35 a-d	12.05 abc	90.24 h	0.50 f-i
$N_0 \times P_1 \times K_1$	41.75 mn	6.25 klm	13.72 abc	12.19 abc	88.82 o	0.59 bcd
$N_0 \times P_1 \times K_2$	55.27 jkl	7.23 ijk	13.45 abc	12.03 abc	89.42 kl	0.55 c-f
$N_0 \times P_2 \times K_0$	43.56 mn	6.42 j-m	13.15 a-d	11.42 a-e	89.05 n	0.54 d-g
$N_0 \times P_2 \times K_1$	56.70 ijk	7.18 i-l	12.42 a-h	11.10 a-g	89.32 l	0.51 e-h
$N_0 \times P_2 \times K_2$	45.31 lm	6.33 klm	12.53 a-g	11.18 a-g	89.20 m	0.52 e-h
$N_1 \times P_0 \times K_0$	63.46 hij	8.44 f-i	12.62 a-g	11.33 a-f	89.70 i	0.50 f-i
$N_1 \times P_0 \times K_1$	54.95 jkl	7.50 ijk	13.76 abc	12.18 abc	88.49 p	0.61 bc
$N_1 \times P_0 \times K_2$	66.86 ghi	8.67 e-i	12.86 a-e	9.94 e-h	90.71 f	0.39 l-o
$N_1 \times P_1 \times K_0$	59.82 ij	8.08 ghi	13.69 abc	12.26 ab	89.55 j	0.55 c-f
$N_1 \times P_1 \times K_1$	75.03 fg	9.64 efg	12.47 a-g	11.36 a-e	91.04 de	0.43 jkl
$N_1 \times P_1 \times K_2$	60.98 ij	8.15 ghi	12.86 a-e	11.67 a-d	90.72 f	0.46 h-k
$N_1 \times P_2 \times K_0$	77.62 ef	9.49 e-h	13.74 abc	12.33 a	89.71 i	0.54 d-g
$N_1 \times P_2 \times K_1$	61.07 ij	8.12 ghi	13.21 a-d	11.96 abc	90.53 g	0.48 g-j
$N_1 \times P_2 \times K_2$	101.56 d	12.71 cd	11.76 d-j	10.78 b-h	91.66 c	0.38 l-o
$N_2 \times P_0 \times K_0$	72.96 fgh	9.55 efg	12.69 a-f	11.21 a-g	88.34 q	0.57 b-e
$N_2 \times P_0 \times K_1$	105.17 cd	12.75 cd	11.43 e-j	10.40 d-h	90.98 e	0.40 k-n
$N_2 \times P_0 \times K_2$	78.49 ef	9.98 ef	11.10 f-j	9.28 h	91.09 d	0.35 m-p
$N_2 \times P_1 \times K_0$	122.95 ab	14.76 a	12.30 b-i	11.16 a-g	90.68 f	0.44 i-l
$N_2 \times P_1 \times K_1$	78.50 ef	9.80 ef	10.75 hij	9.33 h	92.13 a	0.31 p
$N_2 \times P_1 \times K_2$	125.03 a	14.61 ab	11.43 e-j	9.80 fgh	91.73 c	0.34 nop
$N_2 \times P_2 \times K_0$	63.83 hij	7.95 hij	12.81 a-e	11.47 a-e	89.47 jk	0.52 e-h
$N_2 \times P_2 \times K_1$	103.87 cd	12.12 d	10.68 ij	10.67 c-h	90.98 de	0.41 klm
$N_2 \times P_2 \times K_2$	76.07 efg	9.38 e-h	10.60 j	9.75 gh	91.92 b	0.33 op
CV (%)	8.80	10.24	8.20	8.41	0.08	8.14
LSD (0.05)	10.70	1.56	1.67	1.54	0.11	0.06
Level of significance	*	*	*	*	**	**

Figures in a column having different letters differ significantly at 5% level of probability; ** = Significant at p≤0.01 and * = Significant at p≤0.05.

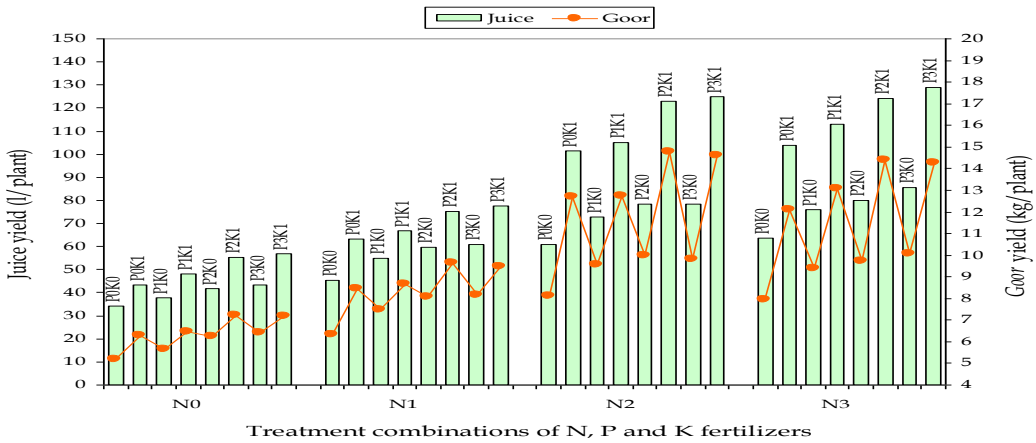

Figure 5. Interaction effects of N, P, and K fertilizers on juice and g*oor* (*jaggary*) yields of date palm (2014-15).

The combination of N, P, and K fertilizers had a significant influence on brix (%), Pol (%), purity (%), and RS content of date palm juice in both the tapping seasons (Table 3 and Table 4). Plants those were received a combination of higher nutrient levels, produced a higher juice yield and it had a negative correlation on brix, sucrose and RS contents.

It was monitored that the interaction of higher nutrient levels increased juice yield with a positive impact on purity. The result indicated that more juice yield as well as goor yield was processed when plants received fertilizers of higher nutrient levels.

Table 4. Interaction effects of N, P, and K fertilizers on brix, pol, purity and RS content of date palm juice (2014-2015)

Interaction (N × P × K)	Brix (%)	Pol (%)	Purity (%)	RS (%)
$N_0 \times P_0 \times K_0$	15.19 a	13.33 a	87.69 s	0.72 a
$N_0 \times P_0 \times K_1$	14.41 a-d	12.67 a-d	87.92 qr	0.67 ab
$N_0 \times P_1 \times K_0$	14.95 ab	13.14 ab	87.83 r	0.70 ab
$N_0 \times P_1 \times K_1$	13.40 c-h	11.91 c-h	88.81 n	0.58 def
$N_0 \times P_2 \times K_0$	14.88 ab	13.11 ab	88.10 p	0.68 ab
$N_0 \times P_2 \times K_1$	13.04 e-j	11.64 d-j	89.29 k	0.54 e-h
$N_0 \times P_3 \times K_0$	14.73 abc	12.96 abc	87.93 q	0.68 ab
$N_0 \times P_3 \times K_1$	12.63 e-k	11.41 e-j	90.34 h	0.47 j-n
$N_1 \times P_0 \times K_0$	13.95 a-e	12.28 a-e	87.96 q	0.65 bc
$N_1 \times P_0 \times K_1$	13.34 d-i	12.15 a-f	91.03 e	0.46 k-o
$N_1 \times P_1 \times K_0$	13.65 b-f	11.91 c-h	87.23 t	0.67 ab
$N_1 \times P_1 \times K_1$	13.04 e-j	11.82 c-i	90.61 g	0.47 j-n
$N_1 \times P_2 \times K_0$	13.50 c-g	12.04 b-g	89.16 l	0.56 d-g
$N_1 \times P_2 \times K_1$	12.86 e-k	11.62 d-j	90.33 h	0.48 i-m
$N_1 \times P_3 \times K_0$	13.37 d-h	12.02 b-g	89.83 i	0.52 f-j
$N_1 \times P_3 \times K_1$	12.22 g-l	11.10 e-k	90.86 f	0.43 m-q
$N_2 \times P_0 \times K_0$	13.31 d-i	11.75 d-j	88.27 o	0.60 cd
$N_2 \times P_0 \times K_1$	12.52 f-k	11.37 e-k	90.84 f	0.44 l-p
$N_2 \times P_1 \times K_0$	13.11 d-i	11.68 d-j	89.11 l	0.55 d-g
$N_2 \times P_1 \times K_1$	12.10 h-l	11.09 e-k	91.22 d	0.41 o-r
$N_2 \times P_2 \times K_0$	12.78 e-k	11.43 e-j	89.41 j	0.52 g-j
$N_2 \times P_2 \times K_1$	12.03 i-l	10.86 g-k	90.27 h	0.45 l-p
$N_2 \times P_3 \times K_0$	12.50 f-k	11.22 e-k	89.78 i	0.49 h-l
$N_2 \times P_3 \times K_1$	11.70 kl	10.76 h-k	91.93 a	0.36 rs
$N_3 \times P_0 \times K_0$	12.51 f-k	11.00 f-k	87.93 qr	0.58 de
$N_3 \times P_0 \times K_1$	11.72 jkl	10.63 ijk	90.70 g	0.42 n-q
$N_3 \times P_1 \times K_0$	12.37 f-l	11.00 f-k	88.92 m	0.53 e-i
$N_3 \times P_1 \times K_1$	11.60 kl	10.56 jk	91.03 e	0.40 p-s
$N_3 \times P_2 \times K_0$	12.21 g-l	10.88 g-k	89.13 l	0.51 g-k
$N_3 \times P_2 \times K_1$	11.57 kl	10.58 jk	91.44 c	0.38 qrs
$N_3 \times P_3 \times K_0$	11.76 jkl	10.62 jk	90.27 h	0.44 l-p
$N_3 \times P_3 \times K_1$	11.10 l	10.19 k	91.80 b	0.35 s
CV (%)	6.36	6.34	0.07	6.50
LSD (0.05)	1.34	1.19	0.11	0.05
Level of significance	*	*	**	**

Figures in a column having different letters differ significantly at 5% level of probability and * = Significant at p≤0.05.

Cost and return of date palm juice and goor production demonstrated that combined application of N, P, and K fertilizers increased goor yield and gross return over control in both seasons (Table 5 and Table 6). In (2013-14) season, the highest gross return (985.60 Tk./plant), gross margin(537.60 Tk./plant), and BCR (2.20) were achieved from treatment combination of $N_2 \times P_2 \times K_2$ (1200g/plant N, 200g/plant P and 1400g/plant K) and in (2014-15) season the highest values of those were 1180.80 Tk./plant, 738.80 Tk./plant and 2.67, respectively obtained from the treatment combination of $N_2 \times P_2 \times K_1$ containing the same amount of nutrients. The lower values of those were recorded from the combinations of lower nutrient levels.

Table 5. Cost and return of date palm juice and goor production for NPK fertilization (2013-14).

Treatment combinations	*Goor* yield (kg/plant)	Gross return (Tk./plant)	Total variable cost (Tk./plant)	Gross margin (Tk./plant)	Benefit-cost ratio (BCR)
1	2	3	4	5 = 3 - 4	6 = 3 ÷ 4
$N_0 \times P_0 \times K_0$	4.67	326.90	229.00	97.90	1.43
$N_0 \times P_0 \times K_1$	5.45	381.50	256.00	125.50	1.49
$N_0 \times P_0 \times K_2$	5.76	403.20	285.00	118.20	1.41
$N_0 \times P_1 \times K_0$	4.67	326.90	243.50	83.40	1.34
$N_0 \times P_1 \times K_1$	5.51	385.70	269.50	116.20	1.43
$N_0 \times P_1 \times K_2$	7.23	506.10	304.50	201.60	1.66
$N_0 \times P_2 \times K_0$	5.75	402.50	264.00	138.50	1.52
$N_0 \times P_2 \times K_1$	8.48	593.60	310.00	283.60	1.91
$N_0 \times P_2 \times K_2$	8.87	620.90	334.00	286.90	1.86
$N_1 \times P_0 \times K_0$	5.63	394.10	267.00	127.10	1.48
$N_1 \times P_0 \times K_1$	7.52	526.40	298.00	228.40	1.77
$N_1 \times P_0 \times K_2$	7.59	531.30	323.00	208.30	1.64
$N_1 \times P_1 \times K_0$	7.97	557.90	292.50	265.40	1.91
$N_1 \times P_1 \times K_1$	8.76	613.20	325.50	287.70	1.88
$N_1 \times P_1 \times K_2$	8.60	602.00	355.50	246.50	1.69
$N_1 \times P_2 \times K_0$	8.10	567.00	306.00	261.00	1.85
$N_1 \times P_2 \times K_1$	9.92	694.40	343.00	351.40	2.02
$N_1 \times P_2 \times K_2$	11.22	785.40	385.00	400.40	2.04
$N_2 \times P_0 \times K_0$	7.09	496.30	304.00	192.30	1.63
$N_2 \times P_0 \times K_1$	11.32	792.40	369.00	423.40	2.15
$N_2 \times P_0 \times K_2$	11.54	807.80	395.00	412.80	2.05
$N_2 \times P_1 \times K_0$	8.93	625.10	333.50	291.60	1.87
$N_2 \times P_1 \times K_1$	11.31	791.70	386.50	405.20	2.05
$N_2 \times P_1 \times K_2$	12.84	898.80	414.50	484.30	2.17
$N_2 \times P_2 \times K_0$	9.04	632.80	344.00	288.80	1.84
$N_2 \times P_2 \times K_1$	11.47	802.90	402.50	400.40	1.99
$N_2 \times P_2 \times K_2$	14.08	985.60	448.00	537.60	2.20

The calculation was based on the current market price. Date palm goor 70.00 Tk./kg (2013-2014).The overall results exhibited that different aspects of date palm juice were significantly affected due to the application of N, P, and K fertilizers either alone or in combination. The highest juice yields were collected from the highest levels of N, P, and K (N_3, P_3, and K_1, respectively) where yields from N_3 (1800 g/plant) and P_3 (300 g/plant) levels were statistically at par with the yields of N_2 (1200 g/plant) and P_2 (200 g/plant) levels, respectively. The highest goor yields were achieved from the levels of N_2 (1200 g/plant), P_2 (200 g/plant), and K_1 (1400 g/plant) but the highest levels of N_3 and P_3 could not produce an additional amount of goor due to having less brix readings in juice.

It was observed that except for purity (%) of juice; brix, Pol, and RS contents are negatively correlated with juice yield. Interactions of the three elements also showed a significant effect on juice yield/plant, goor yield/plant, brix, sucrose, purity, and reducing sugar content of the juice. Juice and goor yields were increased with the combination of higher nutrient levels but with increasing juice yield, quality parameters went downward.

The highest juice yield (128.74 l/plant) was obtained in the $N_3 \times P_3 \times K_1$ treatment combination but the highest goor yield (14.76 kg/plant) was obtained in the $N_2 \times P_2 \times K_1$ and the lowest yields were obtained from the control treatment.

It was monitored that the combinations with higher levels of N and K dominated for both juice and goor yields over the rest of the combinations. Economic analysis of juice and goor production with NPK fertilization from the two years experimentation revealed that the highest gross return, gross margin, and benefit-cost ratio (BCR) were achieved from the combination of $N_2 \times P_2 \times K_1$ applying the doses of 1200g/plant N, 200g/plant P and 1400g/plant K; and could be considered as the best doses for successful date

Discussion

Each of three levels of N, P, and K fertilizers was applied in date palm trees in the (2013-2014) season where observed a significant impact on different attributes of date palm juice. Both juice and goor (jaggary) yields increased significantly due to the application of NPK fertilizers. The quality parameters viz. brix, Pol, purity, and reducing sugar (RS) content of date palm juice were also influenced significantly. With the increasing of juice yield brix, Pol, and RS content were decreased but purity% were increased. Though brix% was decreased with the increasing juice yield but higher amount of goor was obtained from the higher juice yield. Among the three nutrient elements, N and K responded higher irrespective of yield and quality attributes. A significant amount of goor yield was increased in the highest nutrient levels, especially in the case of N and K application. These results were supported by different researchers who reported that application of N, P, and K increased photosynthesis, respiration, vegetative growth, reproduction, cell division, root development, and flowering (Zaid, 2002; Tung et al. 2009).

In the cropping season (2014-2015) where this study was repeated with some modifications including one more additional level of N and P with incremented dose and K had two levels, the control and the highest one as followed in the (2013-2014) cropping season. As of the first year results N, P, and K fertilizers showed significant effects on different aspects of date palm juice in (2014-2015) either applied alone or in combination.

Juice and goor yields increased significantly due to the application of NPK fertilizers.

The quality parameters viz. brix, sucrose, purity, and RS content of date palm juice were also influenced significantly. With the increasing of juice yield brix, Pol, and RS content were decreased but purity% were increased. Though the highest juice yield was harvested applying the highest levels of N, P, and K (N_3, P_3, and K_1, respectively) but the highest levels of N and P could not produce additional goor yield than that of the preceding levels due to having less brix index in the juice.

The highest goor yields were obtained from the levels of N_2, P_2 and K_1 where N, P and K doses were 1200g/plant, 200g/plant and 1400g/plant, respectively.

Jabber et al. (2005) stated that brix indicates total soluble solids in juice and plays an important role in determining the sugar or goor recovery. Combined application of N, P and K fertilizers exhibited significant impact on different aspects of date palm juice in (2013-2014) cropping season.

Higher amounts of juice and goor were achieved from the combinations of the three elements and the highest yields were harvested with the highest doses (1200g/plant N, 200g/plant P, and 1400g/plant K). Like previous year results integrated application of N, P and K fertilizers also exhibited significant impact on different aspects of date palm juice in (2014-2015) cropping season. Higher amounts of juice and goor were also achieved from the combinations of the two or three elements than the sole.

Among the tested three nutrient elements, a comparatively higher response was observed in the combinations of different level of N and K fertilizers. From the combinations of the three elements, the highest juice yield was harvested from $N_3 \times P_3 \times K_1$ where the highest doses (1800 g/plant N, 300 g/plant P, and 1400 g/plant K) were applied but the highest goor yield was harvested from the combination of $N_2 \times P_2 \times K_1$ (1200 g/plant N, 200 g/plant P and 1400 g/plant K).

Munir et al. (1992) reported that N in combination with P and K increased yield per palm and for best results date palm should be fertilized with nitrogen alone provided that the chemical analysis of the soil does not show deficiency of P and K. AL-Baker (1972) reported that addition of 1.2 kg of nitrogen and 1.2 kg of K_2O/palm tree increased the yield 2-3 times and doubled the number of leaves/tree. Sinclair et al. (1981) investigated the effect of different fertilization levels on the growth and chemical composition of date palms and reported that the application of 1100g N for each fruitful tree caused the highest yield and fruit quality. The quality parameters were also influenced significantly in both years by the combined effect of NPK fertilizers.

With the increasing of juice yield brix, pol, and RS content were decreased but purity% were increased. It might be due to when juice yield increases water portion in juice become comparatively higher than the lower yield. Jabber et al. (2005) reported that less reducing sugar is one of the best characteristics of quality attributes. Fageria and Baligar (2005) suggested that the adaptation of a proper fertilization program, including adequate rates, appropriate sources, efficient application methods, and timing are important strategies for obtaining better yield for date palms. For an adult date palm, the amount of nutrients lost through fruits and pruned leaves as well as the worldwide application of fertilizers are to be considered as a basis for the calculation of the amount of fertilizers.

In case of tapping for juice collection from the date palm, a considerable amount of nutrient loss occurs with the exuding sap. Therefore, date plants those are tapping for juice collection need to be fed higher amount of nutrients than that of using for fruit production.

From the calculation of cost and return of date palm juice and goor production in both the years, it was observed that the treatment combination of $N_2 \times P_2 \times K_1$ having the dose of 1200g/plant N, 200g/plant P, and 1400g/plant K gave the highest gross return, gross margin and benefit-cost ratio (BCR) producing highest amount of goor costing less amount of money than the combination of the highest input levels of second year experimentation.

Conclusions

NPK fertilizers significantly increased goor (jaggary) productivity through the improvement of juice quality. Among them, N and K had more noticeable influence than P to yield and quality. The highest juice yield was obtained when applied NPK @ 1800g, 300g, and 1400g/plant, respectively while the highest goor (jaggary) yield was processed NPK @ 1200g, 200g, and 1400g/plant, respectively. Applying NPK fertilizers @ 1200g, 200g, and 1400g/plant can help find the optimal dosages for date palm cultivation for tapping since these had the highest values for goor yield, gross return, gross margin, and BCR with the least amount of variable cost.

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