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Nitrogen Management in Grapes as a Function of Rate and Time of Application

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Abstract

Background/Objectives: Nutrient management plays a key role in growth and yield of grapes. Among the macronutrients, nitrogen is very important because its deficiency and sufficiency both affect yield and quality. Since, this study was aimed to evaluate nitrogen rates and time on yield and nutrient accumulation of grapevines. **Methods**: The experiment was designed in Randomized Complete Block Design (RCBD) in factorial arrangement consisted of N rates as factor (A) i.e. 0.0, 50, 80 and 110 kg N ha^{-1} and time of N application as factor (B) i.e. bud break, at flowering and fruit set. **Findings**: The results showed higher bunch weight on 80 kg N ha^{-1} applied one week before flowering which was 232.66 g for small, 456.77 g for medium and 795.67 g for large bunch along with greater fruit yield of 41.32 t ha^{-1}. However, the increasing N rate (110 kg N ha^{-1}) reduced yield by 15.5% over 80 kg N ha-1 applied at bud break. In case of petiole nutrient concentration, higher N concentration (1.95%) was noted at 110 kg N ha^{-1} but maximum P (0.45%) and K concentration (2.70%) were found at 80 kg N ha^{-1}. The established correlation study indicated that yield was positively and significantly correlated with petiole N (r = 0.87), P (r = 0.92) and K concentration (r = 0.83) indicating yield dependence on nutrient supply. **Applications/Improvements:** From this study, it is suggested that 80 kg N ha^{-1} must be applied one week before flowering but this rate and time might be varied for other soil type.

Keywords: Grapes, Nitrogen, Petiole Nutrient Conc., Rate, Time of Applicate, Yield

1. Introduction

Grapes (*Vitis vinifera*) of family Vitaceae is one of the most popular fruits in the world and is grown in temperate as well as sub-topical climates. Grapes are best grown in all types of climates and soils where the production of other deciduous fruits is restricted. A soil having low water holding capacity sandy loam is the best for its growth. Balochistan is the major grapes producer in Pakistan with some contribution of Khyber Pakhtunkhwa where 1.22 million ton are produced annually but the average yield is 19 tons ha^{-1} which is quite low as compared to its potential yield (i.e. 25 tons ha^{-1})[1]. The province of Balochistan contributes 98 percent to the national grapes production in Pakistan.

A number of varieties of grapes are grown in upland areas of the province. The most famous are, Haita, Kishmishi, Shundokhani, Sahibi and Shekhali are com-

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monly grown popular commercial varieties in Quetta, Pishin, Killa Abdullah, Mastung, Kalat, Loralai and Zhob districts[2]. Like other fruit plant, grapes also have different growth stages in its annual life cycle including bud break, vegetative growth, bloom, fruit set, ripening and leaf fall during autumn and then undergo dormancy period in winter[3]. Through these growth stages, grapevines get hardly 100 days from setting of berry up to harvesting.

Nutrients mining from soil occurs in the form of removal by fruits as well as nutrient use efficiency of fruits[4,5]. Nutrient use of efficiency is affected by variety, growth, and yield. Among the macronutrients, N use efficiency of grapes ranged from 20 to 40%, P 5-20% and K 50-100% respectively. Judicious use of nutrients envisages saving on natural resources for future use and protecting soil, water and air from pollution. Modern nutrient management strategy has shifted its focus towards the concept of practical sustainability with the components of eco-friendly approach to growers and to the crops.

The macronutrients such as N, P and K plainly affect growth of grapevines particularly in bud initiation and grapes' bunches differentiation as potential yield component leading to current year yield production[6]. The scientific literature has shown that the status of these macronutrients results in the determination of target yield i.e. more nutrient accumulation in petiole ensure higher and desired yield provided that other factors such water and cultural management practices are kept conducive. It is evidenced that potential yield of grapevines found in previous season is affected by petiole nutrient status at time of dud initiation and bunch differentiation[7-9].

Nitrogen use efficiency varies from 20 to 40% in grapes and depends on the status of organic matter in soil and doses of nutrient applied. N use efficiency was higher at lower doses of applied N[10]. The efficiency of P is very low and ranged from 5 to 15%. The use efficiency of K ranged from 50 to 100%. Which might be due priming effect of applied potassium on soil potassium?

Nitrogen is one of the primary nutrients that plants required in higher amount including grapevines. It makes up an important of part of protein, nucleic acid, all plant tissues and is integral component of chlorophyll. In both cases of deficiency and sufficiency, plant growth and yield is suffered to great extent. Plant vegetative growth is decline when N is supply limited and in severe N deficiency plant growth is stunted and leaves turned chlorotic. However, higher N application boost up vegetative growth reflecting dense canopies making management practices difficult leading to poor bud initiation, lower fruit set and berries in bunch become compacted. Such compacted bunches become susceptible to fungal attack and rotting of berries occurs[11].

The timing of N fertilizers, like other nutrients, should occur when demand is high and uptake is rapid. Nitrogen is needed most during the period of rapid vegetative growth, which occurs during the spring, from budbreak to early berry development. It is during this period that new growth may accumulate up to 50% of its annual N requirement[12]. Because active root growth and mineral uptake is generally minimal during the budbreak period, N demand is met primarily from reserves stored in the roots and other permanent woody structures (trunk, cordons and canes). The amount of N remobilized from permanent structures between budbreak and fruit set account for up to 40% of that needed by shoots, leaves and clusters[13]. Since the need for N is most critical in the spring and highly dependent on reserves, it can be inferred that the need for soil N is minimal very early in the season and that fertilizers should be applied when vines can best absorb and assimilate N as a part of the reserve while minimizing losses thorough leaching and denitrification[12,14]. In view of the importance of N management in grapevines, the present study was conducted to find out the most appropriate rate of N requirement of grapevines for enhancing yield and to observe the effective timing of N application on growth, yield and quality of grapes.

2. Materials and Methods

The soil of entire Pakistan including Balochistan is calcareous and alkaline in nature. Nutrients availability and efficiency is quite low in such soil. Grapes are grown in three districts of Balochistan i.e. Pishin, Killa Abdullah and Mastung. The mismanagement of N fertilization in grapevines resulted in low yield of poor quality. To evaluate nitrogen rates and time of application, a field study was conducted at Nawabad district Pishin Balochistan, Pakistan during 2016-17. The grapevine variety was shundakhani which were grown in trenches with 12 grapevines in each trench. A complete trench was selected for one treatment and there were 36 trenches chosen for this study. The experiment was designed in Randomized Complete Block Design (RCBD) in factorial arrangement consisted of N rates as factor (A) and time of N application as factor (B) which were replicated thrice. The treatments were included four Nitrogen (N) rates as factor A i.e. 0.0, 50, 80 and 110 kg N ha^{-1} while three time of N application such as bud break, at flowering and fruit set.

At the time of late spring and after harvesting of grapes, the recommended doses of P and K were applied according to the general recommendation of NFDC for grapes. Nitrogen was applied as per treatment. Zinc (zinc sulphate) was sprayed as a 1.0% dormant spray in February and 0.05% iron solution (using sequestrine) was sprayed in May to meet the requirement of Zinc and Iron of grapes.

Before the application of treatments, composite soil sample was collected from the grapevines yard and analysed for physicochemical properties and macronutrients including soil mechanical analysis, pH, EC, organic matter, total nitrogen, AB-DTPA extractable P and K. Hydrometer method was used for soil mechanical analysis[15], soil pH and EC were determined in 1:5 soil and water suspension at 25^{o}C according to the method described by McKeague[16] and McLean[17], organic matter by oxidizing method[18-20], AB-DTPA extraction solution was used for extracting P and K[21]. In the clear filtrate of AB-DTPA soil extract, phosphorus was determined on Spectrophotometer at 880 nm wavelength and potassium on Flame Photometer.

Leaf samples were collected for petioles at veraison with at least 75 to 100 leaves from each treatment. The leaves opposite the bottom flower cluster were collected and petioles were separated from leaf blade and then put in the paper envelopes, labelled and delivered to the Laboratory of Soil and Water Testing of ARI Quetta the same day and stored it over there at 20^{o}C for next coming working day. The samples were decontaminated and washed, oven dried at 80^{o}C, ground to 20 mesh and stored in plastic bags at 4^{o}C in the Lab. for analysis of N, P and K. Weighed 0.3 g of the prepared plant sample and wet digested using hot sulfuric acid with repeated additions of 30% hydrogen peroxide (H_2O_2) until the digestion was completed, then this digest was used for the determination of nitrogen, phosphorus and potassium[22]. For phosphorus, Pipetted 10 ml of the digest into a 100 ml volumetric flask, added 10 ml ammonium-vanadomolybdate and diluted the solution with Deionized water up to the mark. Then, read the absorbance of the blank, standards, and samples after 30 minutes at 410-nm wavelength on Spectrophotometer. The potassium in the digest was determined directly by Flame Photometer. Whereas, total nitrogen was determined by Kjeldhal method[23].

2.1 Statistical Analysis

The data was subjected to statistical analysis using two ways ANOA and LSD test at alpha level 0.05 was applied for comparison of mean. All statistical analysis was computed on Statistix 8.1 software (MathSoft Inc., Cambridge, MA, USA).

3. Results and Discussion

The soil of grapevines yard was sandy clay loam in texture with 48.6% and 26.7% silt and 24.7% clay fraction. Further, the soil was alkaline in reaction (pH 8.12) and non-saline (EC_e 2.34 dSm^{-1}) having low organic matter contents (0.54%). The soil nutrient status of the grapevines yard indicated that total nitrogen (0.027%) and AB-DTPA extractable phosphorus (2.21 mg kg^{-1}) were low but AB-DTPA extractable potassium (118.5 mg kg^{-1}) was in medium range.

The effect of N rates and time of application on grape bunch weight and yield showed variable values that were ranging from 124.8-345.15 g small bunch, 229.0-692.66 g medium bunch, 473.0-1071.0 g large bunch and 18.0-

Table 1. Effect of Nitrogen rates and application time on bunch weight and yield of grapes

Treatment		Bunch weight (g)			Yield (ton ha^{-1})
		Small	Medium	Large	
Nitrogen rates					
0.0 N kg ha^{-1}		162.03 c	281.94 c	563.67 c	26.71 c
50 N kg ha^{-1}		231.67 b	417.72 b	765.33 b	41.32 b
80 N kg ha^{-1}		281.50 a	553.51 a	883.67 a	48.63 a
110 N kg ha^{-1}		233.98 b	424.08 b	761.22 b	40.03 b
S.E.		**4.07**	**11.88**	**10.96**	**0.77**
LSD at p<0.5		**8.44**	**24.63**	**22.73**	**1.60**
Time of N application					
At bud break		219.54 b	393.66 b	698.58 c	36.32 c
At flowering		232.66 a	456.77 a	795.67 a	41.64 a
At fruit set		229.68 a	407.50 b	736.17 b	39.55 b
S.E.		**3.52**	**10.28**	**9.48**	**0.67**
LSD at p<0.05		**7.31**	**21.33**	**19.67**	**1.38**
Interaction					
N rates	x N Time				
1	1	154.43 h	276.92 g	568.70 f	24.53 f
1	2	159.40 gh	288.96 g	554.33 f	28.36 e
1	3	172.27 g	279.93 g	568.00 f	27.22 ef
2	1	205.93 f	355.18 f	691.67 e	38.33 d
2	2	248.50 c	459.53 de	832.00 c	44.08 b
2	3	240.57 cd	438.29 f	772.30 d	41.55 bc
3	1	272.27 b	547.23 ab	819.33 c	44.20 b
3	2	292.07 a	588.96 a	954.70 a	52.13 a

Table 1 Continued

3	3	280.17 ab	524.30 bc	877.00 b	49.57 a
4	1	245.53 c	395.31f	714.67 e	38.26 d
4	2	230.67 de	459.53 de	841.60 bc	41.98 bc
4	3	225.73 e	387.29 f	727.33 d	39.86 ce
S.E.		**7.05**	**20.57**	**18.97**	**1.34**
LSD at p<0.05		**14.61**	**42.66**	**39.35**	**2.77**

46 t ha^{-1} fruit yield respectively. While petiole nutrient concentration (N, P and K) of grapes under the influence of N rate and time of application were also variable, the overall N concentration in petiole was ranged from 0.41 to 2.23% with mean value of 1.28%, P was ranged from 0.09 to 0.58% with mean value of 0.29% and K was ranged from 0.11 to 2.95% with mean value of 2.03%.

The analysis of variance for small, medium and large bunch of grapes showed significant differences across N rates, N time of application and their interaction shown in Table 1. Further N rates and N time of application also expressed highly significant differences for grapes yield ha^{-1} but the interaction of N rates x N time of application was found non-significant. The effect of N rates showed significant ($p<0.05$) differences for bunch weight and yield. In each grapevines, bunches were not of the same size and weight but comprise of small, medium and large bunches. All the three categories of bunches manifested statistically higher weight on N rate of rate of 80 kg ha^{-1} but the increasing N rate resulted in reduction of the respective weight. N rates of 50 and 110 kg ha^{-1} expressed at par differences for bunch weight and yield which were higher over control. The effect of N time of application on bunch weight and yield was significant ($p<0.05$) and higher bunch weight was recorded when N was applied one week before flowering which was 232.66 g for small, 456.77 g for medium and 795.67 g for large bunch along with greater fruit yield of 41.32 t ha^{-1} followed by 229.68, 407.50, 736.17 g small, medium and large bunch with 39.55 t ha^{-1} when N was applied at fruit set. Statistically, N application at bud break and at fruit set exhibited statistically at differences for small bunch (Table 1). These results are supported by the findings[24] who reported that N application at bloom exhibited less dense canopy with higher yield.

The interactive effect of N rates and time of application on bunch weight was highly significant but non-significant for grapes yield. Bunch weight of small, medium and large exhibited greater weight on 80 kg N ha^{-1} when applied one week before flowering while greater but non-significant grapes yield was recorded on 80 kg N ha^{-1} when applied either at one week before flowering or at fruit set. However, the increasing N rates resulted in reduction of both bunch weight and yield. Consequently 15.5% yield was reduced in the interaction of 110 kg N ha^{-1} x at bud break as compared to 80 kg N ha^{-1} x at bud break followed by 24.2% yield reduction when 110 kg N was applied either at flowering or fruiting. It demonstrates that the rate of N is very important for high grape yield production. Because both lower and higher N rates affect yield contributing factors and yield i.e. low rates does not meet N requirement while higher rates boost up vegetative growth over reproductive growth leading to decline in yield. The comparison of N time of application, this study demonstrates that maximum petiole N accumulation was observed when N was applied at flowering

Table 2. Effect of Nitrogen rates and application time on petiole nutrient concentration of grapes

Treatment		Petiole nutrient concentration (%)		
		N	P	K
Nitrogen rates				
0.0 N kg ha^{-1}		0.58 d	0.14 d	0.99 c
50 N kg ha^{-1}		1.12 c	0.25 c	1.84 b
80 N kg ha^{-1}		1.46 b	0.45 a	2.70 a
110 N kg ha^{-1}		1.95 a	0.32 b	2.59 a
S.E.		**0.03**	**0.007**	**0.081**
LSD at p<0.5		**0.06**	**0.015**	**0.168**
Time of N application				
At bud break		1.17 c	0.27 c	1.93 b
At flowering		1.37 a	0.29 b	2.12 a
At fruit set		1.30 b	0.32 a	2.04 ab
S.E.		**0.026**	**0.006**	**0.070**
LSD at p<0.05		**0.054**	**0.013**	**0.146**
Interaction				
N rates x N Time				
1	1	0.54 h	0.14 h	1.10 d
1	2	0.66 g	0.15 h	1.09 d
1	3	0.55 h	0.14 h	0.78 e
2	1	0.95 f	0.23 g	1.51 c
2	2	1.23 e	0.28 ef	2.01 b
2	3	1.18 e	0.26 f	2.00 b
3	1	1.36 d	0.42 c	2.57 a
3	2	1.57 c	0.49 a	2.76 a

Table 2 Continued

3	3	1.46 d	0.45 b	2.77 a
4	1	1.86 b	0.29 e	2.54 a
4	2	1.99 a	0.34 d	2.62 a
4	3	2.01 a	0.32 d	2.62 a
S.E.		**0.052**	**0.013**	**0.140**
LSD at p<0.05		**0.108**	**0.026**	**0.291**

immediately following by at fruit set. It is because during active growth period the demand of N increases leading to higher uptake rate which is observed in vines when N was applied at flowering followed by fruit set (Table 1).

The supply and uptake of plant essential nutrients particularly the macronutrients such as N, P and K to grapevines s is very important for obtaining higher and quality yield. In this study, the grapes petiole nutrient concentration at veraison was investigated across N rates and time of application. The analysis of variance for petiole N, P and K concentration showed significant differences across N rates and N time of application but non-significant for their interaction shown in Table 2, except K which also showed significant differences at the interaction of N rates x time of application. The LSD test ($p<0.05$) for comparison of mean showed that higher petiole N concentration (1.95%) was recorded at higher N rates of 110 kg ha^{-1} while maximum P (0.45%) and K concentration (2.70%) were found at 80 kg N ha^{-1} and their lower concentration were exhibited by control vines where no N was applied. However, petiole K concentration on 80 and 110 kg N ha^{-1} was statistically at par. In case of N time of application, the LSD test ($p<0.05$) for comparison mean revealed greater petiole N concentration (1.37%) in vines when N was applied one week before flowering whereas maximum P (0.32%) was recorded when N was applied at fruit set but petiole K concentration manifested statistically higher but non-significant at both time of application i.e. at flowering and at fruit set. However, all the three macro nutrients expressed low petiole concentration when N was applied at bud break I (Table 2)[25]. That the response of grapevine to N rates depends on cultivar. The results reported[26,27] are in accordance with findings of this study that N application time for grapevine is one week before flowering or one week later after bloom where more N uptake occurs on this growth stage of grapevine.

The interactive effect of N rates and time of application on petiole nutrient concentration was significant. Maximum but non-significant petiole N concentration (1.99 and 2.01%) was recorded in grapevines s when 110 kg N ha^{-1} was applied at flowering and fruit set (Table 2). In case of petiole P concentration, the interaction of 80 kg N ha^{-1}x at flowering time expressed maximum petiole P concentration (0.49%) followed by 0.45% when same N rate was applied at fruit set. However, non-significantly higher petiole K concentration was observed in vines when 80 and 110 kg N was applied at all three N time of application. It is evidenced that the increasing N rates resulted in reduction of petiole P accumulation that might be due to growth dilution of grapeviness. The higher N rates applied either at flowering or fruit set accelerated petiole N accumulation leading to more vegetative growth which was proved detrimental for yield production. However, the higher N rates did not affect petiole K accumulation. One reason is that the soil

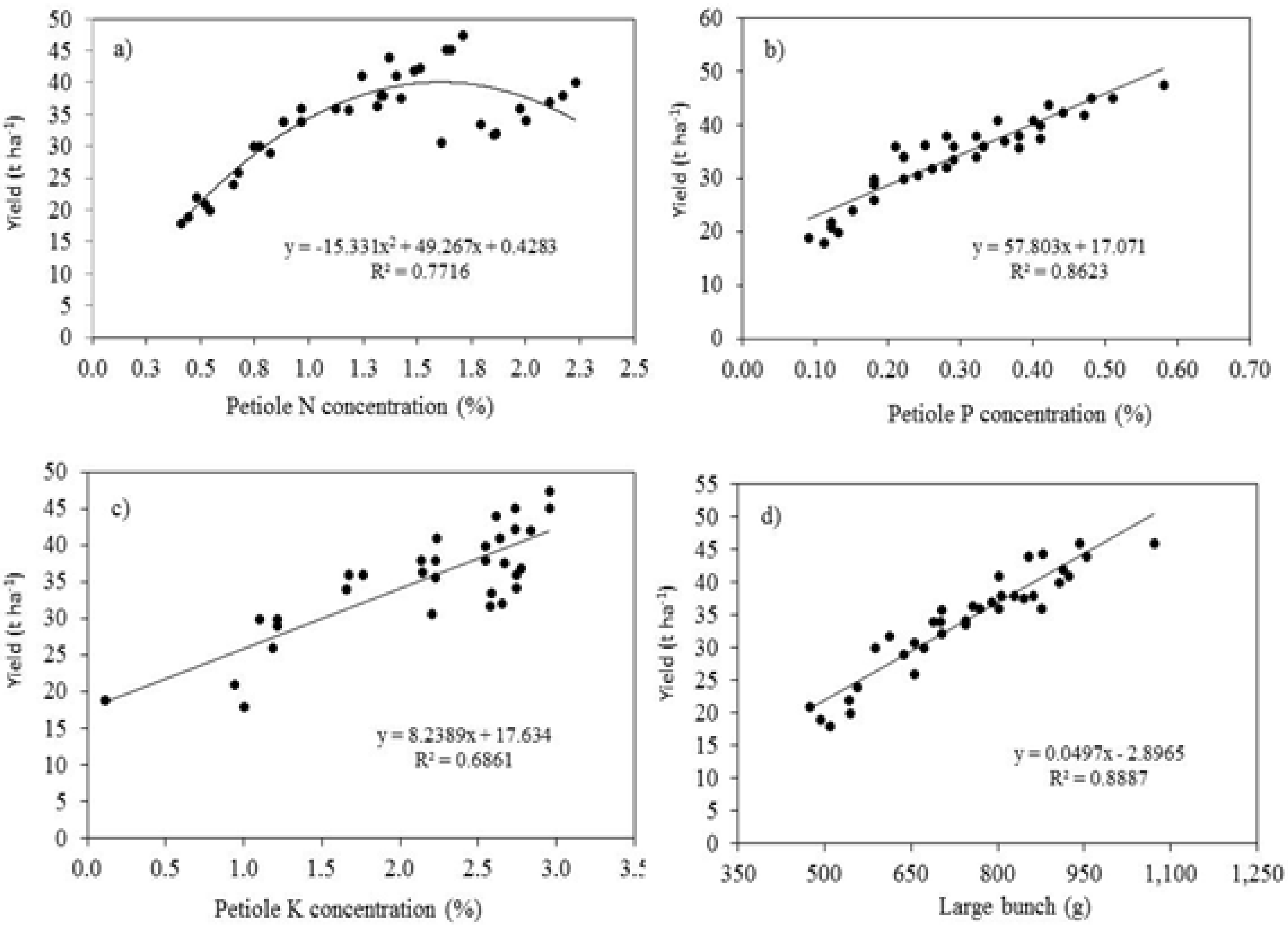

Figure 1. . (a) Polynomial correlation between grape fruit yield and petiole N concentration, (b) Linear correlation between grapes fruit yield and P, (c) Yield and petiole K concentration and (d) Fruit yield and large bunch.

already contain K concentration in adequate range that resulted in more K uptake which is also reported[28] that in comparison to other plants grapevine can bitterly use so[29] that on the basis of nutrient accumulation in grape these can arranged in two groups: 1. The nutrients like N, P, K and Mg accumulate up to berry growth, 2. The nutrient like Ca continue accumulation up to veriason. This is the reason that petiole nutrients status fluctuated over time of N application. Similarly, researchers like[30,31] reported that among the macronutrients, N is considered important for growth, yield and quality of grapevine because it greatly change grapevines composition than other macronutrients and optimum supply of N at the right time helps plants to withstand stress.

The extent of relationship between grapes yield and petiole nutrients concentration under the influence of N rate and time of application as predicted in Figure 1 revealed that yield was positively and significantly correlated with petiole N, P and K concentration. There was polynomial correlation between yield and petiole N concentration (r = 0.87) which indicate that yield was increased with N application to some extent but the increasing rates resulted in yield decline (Figure 1a). In case of petiole P and K concentration and bunch weight, the grapes yield was positively and significantly correlated with petiole P concentration (r = 0.92), K concentration (r = 0.83) and large bunch (r = 0.94) (Figure 1b-d). The correlation evidenced that for higher yield the nutrient supply is utmost important particularly the right dose at the right time. The change in nutrient ultimately alter yield. So, the wise use of nutrients ensure sustainable and higher yield. These correlations are supported[32] who found highly significant correlation between leaf N concentration and function of photosynthetic system. Highly significant correlation between berry dry mass and berry N concentration (r = 0.98), P concentration (r = 0.96) and K concentration (r = 0.98) was established[33].

4. Conclusion

From this study it was inferred that changing nitrogen rates and Time ultimately affect grapevines growth and yield. Among the evaluated N rates and time of application, 80 kg N ha^{-1} when applied one week before flowering increased bunch weight, yield and petiole P and K concentration but higher petiole N concentration as noted at 110 kg N ha^{-1} resulted in yield reduction. The established correlation study indicated that yield was positively and significantly correlated with petiole N, P and K concentration indicating yield dependence on nutrient supply. So, it is suggested that 80 kg N ha^{-1} must be applied one week before flowering but this rate and time might be varied for other soil type.

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