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Leaf Boron and Potassium and Nut Weight in Coconut (*Cocos nucifera* L.) as Affected by their Individual and Combined Applications in *Terai* Region of West Bengal

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A B S T R A C T

A major limiting factor in harnessing the potential nut weight in coconut (*Cocos nucifera* L.) in *terai* region of West Bengal is low leaf potassium and boron contents. For ascertaining the same in quantitative terms, an experiment was undertaken to evaluate the effects of potassium applied as muriate of potash @ 900, 1200 and 1500 g and boron as borax @ 25, 50, and 100 g/palm/year on leaf boron and potassium contents and nut weight in coconut during 2014-15 and 2015-16. The index leaf (14th frond) was used for determining the nutrients at 6 and 12 months after application. Application of the nutrients resulted in a significant increase in the respective nutrient content of the leaves. The combined application of the nutrients at the intermediate level (1200 g MoP with 50 g borax) recorded the maximum nut weight (1948.50 g) at 7 month age of nuts with 1.97% potassium and 24.52 mg/kg boron content of the leaves. The increase in nut weight was observed between from 6th to 7th months and thereafter, decreased progressively up to 12th months Further increase in the rate of application caused a decline in nut weight, despite an increase in the nutrient contents of the leaves. The combined application of the nutrients beyond the intermediate level also revealed the same trend, implying a negative interaction effect. Nut weight showed a positive correlation with increased leaf potassium and boron content only upto a certain level of application. Beyond this 'greater than the optimum' level, the nutrients resulted in a negative effect on nut weight.

Introduction

Terai region of West Bengal witnessed a sharp rise in the acreage under coconut (*Cocos nucifera* L.) in the last couple of years. The crop in the region is grown in homestead gardens and as a plantation crop too, and appears to be very promising in economic returns. The nut weight and yield is however, very poor - in terms of both quality

and quantity - due mainly to lack of nutrient management and irrational application of fertilizers. Coarse texture of the soils, high rainfall of the region, low soil pH, and nutrient removal by leaching and the crop contribute to multiple nutrient deficiencies. Among the deficient plant nutrients, potassium (K) and boron (B) have proved to be more significant than others. The two nutrients contribute to increased nut size, nut weight, and softness of the biomass of the copra, improved kernel development, faster translocation of sugars and starch from leaves to nuts, and higher sweetness of the coconut water. In addition, high leaf K content helps regulate the plant's metabolism, opening and closure of the stomata required for water economy, activation of many crucial enzymes, maintenance of cation-anion balance in the cells, and control the transport of the metabolites required for cell division. However, there has so far been no study on the effects of B and K on such aspects in such soils. A study was therefore, undertaken to evaluate the effects of B and K applied alone or in combination on the concentrations of the nutrients in the leaves and relates these concentrations to the nut weight in coconut grown in the *terai* region of West Bengal.

Materials and Methods

The experiment was conducted during 2014-15 and 2015-16 at the Instructional Plots of the Department of Plantation Crops and Processing, Uttar Banga Krishi Viswavidyalaya, West Bengal. The experimental field is located at 43 m above mean sea level at 26°19′86″N latitude and 89°23′53″ E longitude. Physico-chemical properties of the soil analysed by standard methods were: texture- sandy loam, pH - 5.45 (Jackson, 1973), electrical conductivity - 0.06 dsm^{-1} (Jackson, 1973), organic carbon - 0.93% (Walkley and Black, 1934), available N - 159. 32 kg/ha (Subbiah and Asija, 1956), available P - 23.15 kg/ha (Bray and Kurtz, 1945), available K – 87.15 kg/ha (Jackson, 1967), and available B – 0.59 mg/kg (Hot water extractable as proposed by Berger and Truog, 1939).

The experiment was laid out in Factorial Randomised Block Design with 9 treatments, with three different levels of potassium viz. K_1, K_2, and K_3 @ 900, 1200 and 1500 g of K_2O (as MoP, 60% K_2O) and three levels of boron viz. B_1, B_2, and B_3 @ 25, 50, and 100 g (as borax, 10.5% B) per palm per year at a spacing of 7.5 x 7.5 m in 9 years old East Coast Tall. Each treatment was replicated 4 times The nine different treatment combinations were as follows:T_1: B_1K_1: 25 g borax/palm + 900 g K_2O/palm, T_2: B_1K_2: 50 g borax/palm + 1200 g K_2O/palm, T_3:B_1K_3: 25 g borax/palm + 1500 g K_2O/palm, T_4:B_2K_1: 50 g borax/palm + 900 g K_2O/palm, T_5: B_2K_2: 50 g borax /palm + 1200 g K_2O/palm, T_6: B_2K_3 50 g borax/palm + 1500 g K_2O/palm, T_7: B_3K_1: 100 g borax/palm + 900 g K_2O/palm, T_8: B_3K_2: 100 g borax/palm + 1200 g K_2O/palm and T_9: B_3K_3: 100 g borax /palm + 1500 g K_2O/palm. All the palms were fertilized uniformly with 500 g N (as urea, 46% N) and 320 g of P_2O_5 (as SSP, 16% P_2O_5) per palm along with the required amount of boron and potassium as per the treatment combinations. Half of the doses of the nutrients were applied in May, 2014 as pre-monsoon application, while the remaining half was applied in September, 2014 as post-monsoon application. The same fertilizer schedule was repeated for the year 2015. The fertilizers were applied at 180 cm away from the base of the palms (De Silva, 1968).The initial soil samples at 0-30 cm depth were collected at random before commencement of the study; thereafter, sampling was done at 6 month intervals at a the same depth at sites 1.8 m away from the trunk of the palm. For the determination of boron and potassium content of leaf, the leaf samples were collected from

the index leaf *i.e.* 14th fronds for analysis before application of the fertilizers and subsequently at 6 and 12 months after application. The 14th fronds were chosen as the index leaf for analysis of as suggested by Reuter and Robinson (1997). The leaf samples were digested by tri-acid mixture and the acid digests as such or after proper dilution were analysed for their potassium content by flame photometry as described by Muhr *et al.,* (1965). For determining boron, the digests were analysed by the method suggested by Berger and Truog (1939). The coconut nut weight were recorded at intervals of 6th, 7th, 8th, 9th and 12th month age of nuts during 2014-15 and 2015-16.

Results and Discussion

Effect of boron and potassium application and their interactions on leaf K content

The results pertaining to the effect of application of boron at different levels on leaf K content are presented in Table 1 and showed that there was a little variation in leaf K content between the two consecutive years of study. However, with increase in the level of boron application from B_1 to B_2, there was significant increase in leaf K content. Increased K uptake at an optimum level of soil boron has been reported by Samet *et al.,* (2015) in pepper. With further increase in boron application rate, the leaf K content decreased substantially. This decrease was might be due to the toxic concentration of boron in the soil at B_3 level of boron application. Mengel and Kirkby (2001) reported that excess supply of boron in growth medium reduced uptake of K and *vice versa*.

The results in relation to the effect of potassium applications at different graded levels on the leaf K content are also depicted in Table 1 and showed that there was high consistency in leaf K content between the results of the two years. In any case, with increase in potassium supply, the nutrient continues to be increasingly absorbed as seen in increased leaf K content. Venkitaswamy *et al., (*2011) also reported results in similar lines.

The results revealed that the leaf K content was the highest in B_1K_3 treatment followed by B_2K_3 and B_2K_2 treatments and it was lowest in B_3K_1 followed by B_1K_1 and B_3K_3 (Table 1). Boron-potassium interactions at the applied levels and combinations caused the differences in the leaf K content. The results of the study suggested that, there was synergistic interaction effect between K and B in the case of B_1K_3, B_2K_3, and B_2K_2 treatments resulting in increased K uptake. The interaction between these two nutrients was antagonistic also in B_3K_1 and B_3K_3 combinations. Mengel and Kirkby (2001) observed that B and K interaction was negative with an excess supply of boron.

All the levels of boron and potassium and their interaction effects pertaining to leaf K content were showed progressively decreasing trend from 6 month to 12 months after soil application of boron and potassium.

Effect of application of boron and potassium and their interactions on leaf B content

The results pertaining to the effect of boron application at different rates on leaf B content are presented in Table 1. A careful approval of results showed a negligible variation in leaf B content between the results of the two years. With increase in the level of boron application, there was significant and proportionate increase in leaf boron content. B content in leaf increased. Similar results have been reported by Moura *et al.,* (2013) and Nistane *et al.,* (2011) in coconut.

Table.1 Effect of boron and potassium application and their interaction on potassium and boron content of leaves

	Leaf K content (%)						Leaf B content (mg/kg)					
Levels of Boron	**6 months (December)**			**12 months (June)**			**6 months (December)**			**12 months (June)**		
	2014-15	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**
B_1	1.72	1.73	1.73	1.03	1.03	1.03	14.09	14.52	14.30	8.932	9.034	8.983
B_2	1.82	1.84	1.83	1.06	1.05	1.06	22.58	22.67	22.62	11.79	12.05	11.92
B_3	1.31	1.31	1.31	0.86	0.86	0.86	30.79	31.27	31.03	14.77	14.61	14.69
SE(m)±	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.16**	**0.19**	**0.15**	**0.25**	**0.25**	**0.22**
LSD (P=0.05)	**0.02**	**0.01**	**0.01**	**0.02**	**0.03**	**0.02**	**0.48**	**0.56**	**0.43**	**0.72**	**0.73**	**0.63**
Levels of Potassium	**6 months (December)**			**12 months (June)**			**6 months (December)**			**12 months (June)**		
	2014-15	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**
K_1	1.12	1.12	1.12	0.86	0.85	0.86	23.22	23.63	23.42	12.25	12.34	12.29
K_2	1.74	1.75	1.75	1.03	1.03	1.03	23.24	23.78	23.51	12.39	12.37	12.38
K_3	1.99	2.00	2.00	1.06	1.05	1.06	21.00	21.05	21.02	10.84	10.98	10.91
SE(m)±	**0.01**	**0.00**	**0.01**	**0.01**	**0.01**	**0.01**	**0.16**	**0.19**	**0.15**	**0.25**	**0.25**	**0.22**
LSD (P=0.05)	**0.02**	**0.01**	**0.01**	**0.02**	**0.03**	**0.02**	**0.48**	**0.56**	**0.43**	**0.72**	**0.73**	**0.63**
Treatment combinations	**6 months (December)**			**12 months (June)**			**6 months (December)**			**12 months (June)**		
	2014-15	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**
B_1K_1	1.10	1.10	1.10	0.83	0.83	0.83	14.22	14.73	14.47	9.60	9.48	9.54
B_1K_2	1.75	1.75	1.75	1.04	1.03	1.03	15.73	15.98	15.85	9.98	10.26	10.12
B_1K_3	2.32	2.33	2.33	1.22	1.22	1.22	12.31	12.85	12.58	7.22	7.36	7.29
B_2K_1	1.29	1.30	1.29	0.99	0.98	0.98	22.08	22.32	22.20	11.39	11.76	11.58
B_2K_2	1.96	1.97	1.97	1.10	1.10	1.10	25.00	24.05	24.52	13.05	13.31	13.18
B_2K_3	2.21	2.24	2.23	1.10	1.08	1.09	20.67	20.05	20.36	10.91	11.06	10.99
B_3K_1	0.97	0.97	0.97	0.75	0.75	0.75	33.42	34.29	33.86	16.18	15.87	16.02
B_3K_2	1.52	1.53	1.52	0.96	0.96	0.96	28.93	29.28	29.11	13.72	13.45	13.58
B_3K_3	1.43	1.44	1.43	0.85	0.86	0.86	30.02	30.24	30.13	14.40	14.52	14.46
SE(m)±	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.28**	**0.33**	**0.25**	**0.43**	**0.43**	**0.37**
LSD (P=0.05)	**0.04**	**0.02**	**0.02**	**0.03**	**0.04**	**0.03**	**0.84**	**0.97**	**0.74**	**1.25**	**1.26**	**1.09**

Table.2 Effect of application of boron and potassium and their interaction on nut weight (g) at 6th, 7th, 8th, 9th and 12th months age of nuts

Levels of Boron	6th month			7th month			8th month			9th month			12th month		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
B_1	1717.42	1722.75	1720.08	1801.75	1807.92	1804.83	1726.00	1732.42	1729.21	1624.25	1627.75	1626.00	1189.00	1182.42	1185.71
B_2	1772.50	1778.00	1775.25	1858.25	1863.67	1860.96	1777.25	1784.42	1780.83	1661.92	1670.17	1666.04	1272.00	1261.25	1266.63
B_3	1524.17	1531.92	1528.04	1564.83	1570.67	1567.46	1521.58	1526.42	1524.00	1451.42	1456.83	1454.13	1003.92	999.92	1001.92
SE(m)±	**6.06**	**6.86**	**6.40**	**5.66**	**5.36**	**5.47**	**3.65**	**4.73**	**4.07**	**4.54**	**4.33**	**4.34**	**6.20**	**6.08**	**5.90**
LSD (P=0.05)	**17.79**	**20.13**	**18.80**	**16.61**	**15.75**	**16.07**	**10.72**	**13.89**	**11.95**	**13.33**	**12.70**	**12.73**	**18.20**	**17.84**	**17.32**

Levels of Potassium	6th month			7th month			8th month			9th month			12th month		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
K_1	1611.67	1619.75	1615.71	1663.92	1669.83	1666.88	1617.75	1624.33	1621.04	1522.08	1526.92	1524.50	1075.17	1075.17	1075.17
K_2	1739.75	1745.33	1742.54	1823.08	1827.92	1825.50	1746.58	1752.67	1749.63	1637.75	1643.33	1640.54	1220.08	1213.08	1216.58
K_3	1662.67	1667.58	1665.13	1737.83	1744.50	1740.88	1660.50	1666.25	1663.38	1577.75	1584.50	1581.13	1169.67	1155.33	1162.50
SE(m)±	**6.06**	**6.86**	**6.40**	**5.66**	**5.36**	**5.47**	**3.65**	**4.73**	**4.07**	**4.54**	**4.33**	**4.34**	**6.20**	**6.08**	**5.90**
LSD (P=0.05)	**17.79**	**20.13**	**18.80**	**16.61**	**15.75**	**16.07**	**10.72**	**13.89**	**11.95**	**13.33**	**12.70**	**12.73**	**18.20**	**17.84**	**17.32**

Interaction effect of application of boron and potassium on nut weight (g) at 6th, 7th, 8th, 9th and 12th months age of nuts															
Treatments	6th month			7th month			8th month			9th month			12th month		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
B_1K_1	1669.25	1673.25	1671.25	1730.00	1736.75	1733.38	1686.25	1692.50	1689.38	1588.00	1591.00	1589.50	1123.25	1117.00	1120.13
B_1K_2	1774.50	1779.00	1776.75	1866.00	1871.25	1868.63	1780.50	1789.00	1784.75	1665.75	1670.50	1668.13	1256.50	1249.50	1253.00
B_1K_3	1708.50	1716.00	1712.25	1809.25	1815.75	1812.50	1711.25	1715.75	1713.50	1619.00	1621.75	1620.38	1187.25	1180.75	1184.00
B_2K_1	1692.00	1700.50	1696.25	1756.25	1761.25	1758.75	1705.75	1712.75	1709.25	1600.50	1607.25	1603.88	1150.50	1144.75	1147.63
B_2K_2	1866.50	1870.75	1868.63	1946.25	1950.75	1948.50	1848.75	1855.50	1852.13	1716.25	1723.25	1719.75	1352.00	1345.25	1348.63
B_2K_3	1759.00	1762.75	1760.88	1872.25	1879.00	1875.63	1777.25	1785.00	1781.13	1669.00	1680.00	1674.50	1313.50	1293.75	1303.63
B_3K_1	1473.75	1485.50	1479.63	1505.50	1511.50	1508.50	1461.25	1467.75	1464.50	1377.75	1382.50	1380.13	951.75	963.75	957.75
B_3K_2	1578.25	1586.25	1582.25	1657.00	1661.75	1659.38	1610.50	1613.50	1612.00	1531.25	1536.25	1533.75	1051.75	1044.50	1048.13
B_3K_3	1520.50	1524.00	1522.25	1532.00	1538.75	1534.50	1493.00	1498.00	1495.50	1445.25	1451.75	1448.50	1008.25	991.50	999.88
SE(m)±	**10.49**	**11.87**	**11.09**	**9.80**	**9.29**	**9.48**	**6.32**	**8.20**	**7.05**	**7.87**	**7.49**	**7.51**	**10.73**	**10.53**	**10.22**
LSD (P=0.05)	**30.81**	**34.87**	**32.56**	**28.78**	**27.27**	**27.83**	**18.56**	**24.06**	**20.69**	**23.09**	**22.01**	**22.05**	**31.52**	**30.91**	**30.00**

Fig.1 Effect of born on nut weight (g) at 6th, 7th, 8th, 9th and 12th months age of nuts

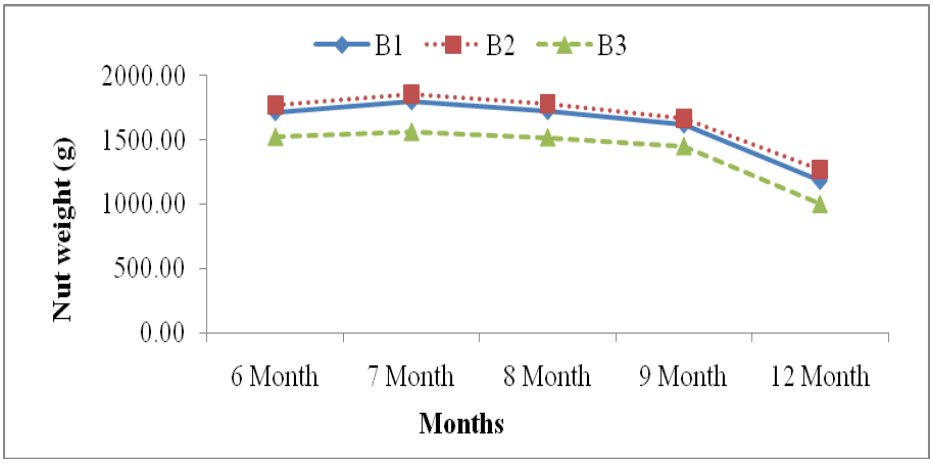


Fig.2 Effect of potassium on nut weight (g) at 6th, 7th, 8th, 9th and 12th months age of nuts

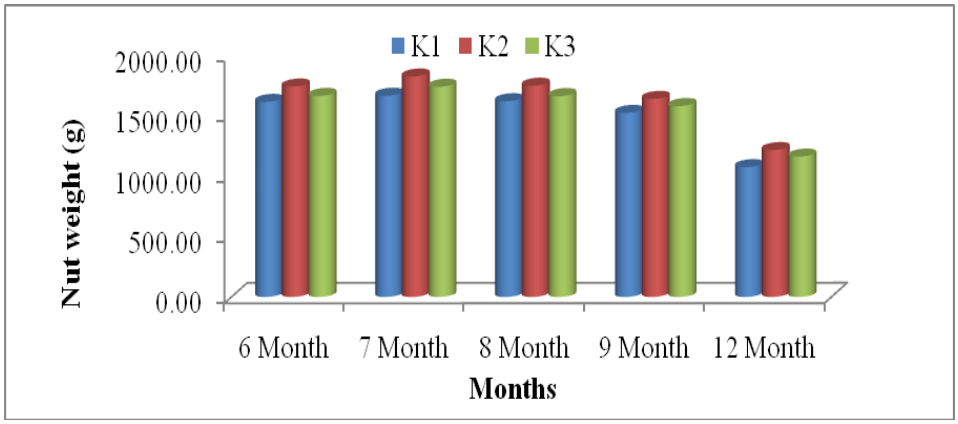
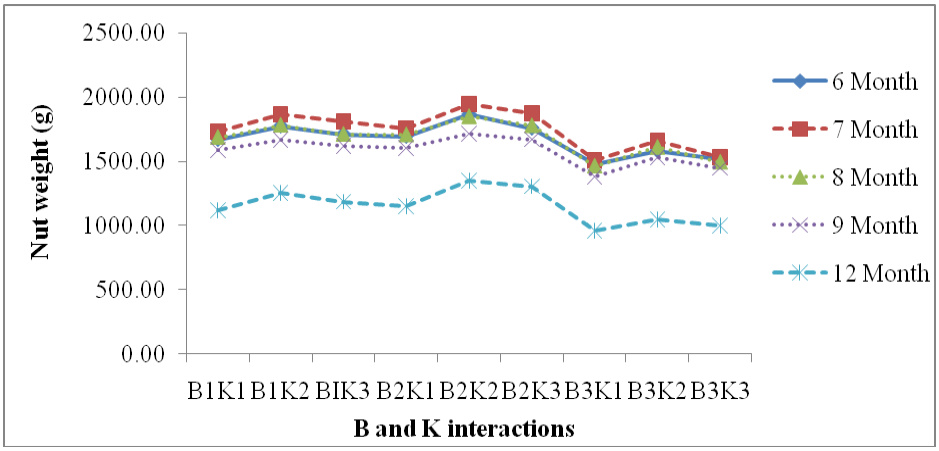


Fig.3 Interaction effect of boron and potassium on nut weight (g) at 6th, 7th, 8th, 9th and 12th months age of nuts



On the other hand, with increase in the level of potassium from K_1 to K_2, there was little increase in the leaf boron content from 23.63 to 23.78 in 2015-16 at 6 months after application and it was statistically at *par* with each other. With further increase in potassium level, there was sharp decrease in boron content of the leaves from 23.78 to 21.05 in 2015-16 and it was statistically significant. This variation suggests negative interaction between B and K at excess levels of available K due possibly to cation-anion imbalance as has been reported earlier by Samet *et al.,* (2015). The same trend was observed in 2014-15 and also in the case of pooled results for the two years.

A perusal of data presented in Table 1 showed that the leaf B content was the highest in B_3K_1 treatment followed by B_3K_3 and B_3K_2 treatments. Boron-potassium interactions at the applied rates and combinations might have caused the differences in the leaf B content. This type of effect may be due to excess application of potassium caused to decrease in leaf B content. The results of the study suggest that as regards to leaf B content, there was synergistic interaction effect between potassium and boron in certain cases and antagonistic interaction in some cases. The results of the study are in agreement with those of present findings confirmed the findings of Ranade-Malvi (2011). Further, it appears that the individual effects of boron and potassium and also their interaction effects pertaining to the leaf boron content had a decreasing trend from 6 to 12 months after soil application of boron and potassium. The continued decrease in leaf boron content may because of the fact that during this period (6 to 12 months), boron might have been utilized in fruit setting, boosts up pollination, seed development, formation of meristimatic tissues, synthesis of cell wall, lignifications maintenances of cell wall structure integrity nitrogen metabolism, and protein biosynthesis. A similar result was also reported by Ahmad *et al.,* (2009).

Effect of boron and potassium application and their interaction on nut weight

The results with relation to effect of graded levels boron at different rates on nut weight at different month age of nuts are presented in Table 2 and Figure 1. The results showed that in both the years, the nut weight was the highest at B_2 level of boron at 6th, 7th, 8th, 9th and 12th month age of nuts after application. With increase in boron level from B_1 to B_2, there was a substantial increase in nut weight at all the months. With further increase in boron to B_3 level, the nut weight was reduced. At B_3 level, there must have been boron toxicity causing hindrance in potassium availability and uptake reflected through decreased nut weight. A similar line reports were reported by Nistane *et al.,* (2011). The maximum nut weight was recorded at B_2 level of boron at 7th month age of nuts after application as evident from pooled result **(**1860.96 g). The increase in nut weight was observed between from 6th to 7th months and thereafter, decreased progressively up to 12th months. The low boron availability in the soils may be the reason for decreased nut weight at B_1 level. Nut weight increase might be due to involvement in hormonal metabolism, increase cell division and expansion of cell and also known to stimulate rapid mobilization of water and sugars in the nut as suggested by Singh *et al.,* (2012).

Table 2 and Figure 2, revealed that the effect of potassium application at different rates on nut weight. The results elucidate that in both the years, the nut weight was the highest at K_2 level of potassium. There was a substantial increase in nut weight when potassium level was increased from K_1 to K_2. The maximum nut weight was recorded at B_2 level of boron at 7th month sage of nuts after application as

evident from pooled result (1825.50 g).With further increase in potassium to K_3 level the nut weight was significantly reduced. Potassium is not reported to cause any toxicity even at a still higher rate of application. As already mentioned, it is possible that potassium at the level is reducing the uptake of some other nutrient such as boron. Many of the functions of potassium and boron are overlapping and at high potassium level, the uptake of boron is often reduced (Mengel and Kirkby, 2001).

Interaction effects of boron and potassium application on nut weight

The results pertaining to boron-potassium interaction effects on nut weight are presented in Table 2 and Figures 3. The nut weight was the highest at 7th month age of nuts after application. The pooled results revealed that among the treatments, B_2K_2 (1948.50 g) was the best and significant over all the treatment combinations followed by B_2K_3 (1875.63 g) and B_1K_2 (1868.63 g) and from 7th month onwards, the nut weight had a continued decrease. The present findings are supported by those of Poduval *et al.*, (1998), Jayalekshmi *et al.*, *(*1988), Apshara *et al.*, (2007) and Angela *et al.*, (2008).The results suggested that for reaching the maximum nut weight, B_2K_2 level should be recommended in coconut plantations under *terai* zone of West Bengal.

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