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EARLY WINTER SPRAY OF LOW BIURET UREA IMPROVES MARKETABLE YIELD AND FRUIT QUALITY OF SWEET ORANGES

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Abstract

The purpose of this study was to determine the optimum time of low-biuret urea (LBU) applied as a foliar spray to improve marketable yield and fruit quality of Sweet Orange (*Citrus sinensis* L. Osbeck.) cv "Blood Red". Two percent solution of LBU was sprayed on 15 years old plants to the point of run off, on 15th of October, November and December in 2004. Simple water spray was used as control. Plants selected for the experiment were grafted on rough lemon (*Citrus jambhiri* Lush.) rootstock and were grown at University of Agriculture Faisalabad (Latitude 31° 25' North; Longitude: 73° 09'), Pakistan. Experiment was laid out in RCBD, using single plant as a treatment unit with three replicates. Foliar spray of 2% LBU on 15th November, 2004 significantly increased total yield (102%) as well as grade-I fruit yield (75%) compared with control. Fruit quality including pulp colour score (40%), TSS (33%), vitamin C (10%), TSS/TA (19%), sugars (44%) and taste score (37%), of November treated samples were significantly greater as compared to control. Significant decrease in fruit weight, fruit diameter, and number of aborted seeds/fruit was recorded in all the treatments as compared to the highest values in control, followed by the treatments applied on 15th of December, October and November, 2004 respectively. Highest value of 108.3g for fruit weight and 56.9mm diameter were found in plants treated on 15th November, 2004. No effect was observed in juice contents, peel weight or acidity with LBU treatments. Overall, foliar spray of 2% LBU applied on 15th November, 2004, produced better results for improving marketable yield and fruit quality of "Blood Red" sweet orange.

Introduction

Citrus is a major fruit crop in Pakistan with 1.70 MMT annual production from 185 thousand hectares (FAO, 2005). Pakistan stands at 13th position among top citrus producing countries and at 10th position among citrus exporting countries of the world (FAO, 2005). Citrus growers in the province of Punjab are concerned for shy bearing, low fruit quality and short life span in sweet oranges cultivation (Ahmed *et al.*, 2007) as compared to 'Kinnow' mandarin, which currently dominates the local citrus industry. Considering the above mentioned facts, citrus growers prone to only "Kinnow" mandarin cultivation. Hence, the local citrus industry has turned into monoculture, and is at risk if there is any epidemic outbreak. At present, per hectare average yield of citrus including "Kinnow" mandarin is about 10 t ha^{-1} (Burhan *et al.*, 2008), in Pakistan, compared to

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world average yield of 30 t ha^{-1}, which is far less (NESPak, 1993). Therefore, there is dire need to address the problems in sweet oranges cultivation in improving per hectare production, fruit quality and life span. This will not only create diversity in citrus production industry but also increase citrus fruits availability for longer period of time.

Plant nutrition, particularly the level of N has more influence on the growth, yield and quality of citrus than any other single plant nutrient (Thompson *et al*., 2002). Foliar N fertilization offers an opportunity to apply a significant portion of the total plant N requirement in a more efficient manner than traditional flood or ground applications (Wright & Pena, 2000). Low-biuret urea (LBU) is recommended for foliar applications on high value horticultural crops. LBU sources have been applied as the foliar component of a typical N application program (Wright & Pena 2000) which limits leaching of nitrogen in groundwater. Embleton *et al*. (1980) estimated that in foliar application, urea which falls other than tree, only 10% of that reached the ground, and 75% of that was volatilized as ammonia. Although application of LBU did not significantly increased total leaf nitrogen at the end of three years however, winter foliar application of LBU at 'Washington Navel' orange significantly increased yield compared to soil application (Ali & Lovatt 1994).

Adequate supply of nitrogen during the critical stages of fruit initiation and development is important to support optimal yields of good quality citrus (Davies & Albrigo, 1994; Tucker *et al*., 1995; Alva *et al.*, 2006). Increased fruit size in 'Washington Navel' was found with LBU application, which was associated with increased contents of ammonia, arginine and polyamines (Corona, 1994). Wright & Pena (2002) reported that fruit size and grade were improved by the application of LBU on 'Washington Navel' sweet oranges, however, there was non-significant difference among treatments in case of juice contents, TSS, TA, TSS: TA, pH and peel thickness, during two years of experimentation. Application of foliar urea is being used to increase fruit size of navel oranges in San Joaquin Valley (Mauk & Takele, 2000). Low-biuret urea applied at maximum peel thickness, improved the commercially important size of 'Valencia' orange fruit (Lovatt, 2000).

A lot of research work has been done using foliar application of low-biuret urea to improve quality production of citrus fruits; however no one had initiated this kind of work in Pakistan to observe the LBU under our conditions. Therefore, this study was initiated to find out the impact of winter foliar application of LBU on fruit yield, marketable packout and quality of 'Blood Red' sweet orange.

Materials and Methods

The study was conducted on 15 years old "Blood Red" sweet orange (*Citrus sinensis* Osbeck L) plants, growing at Experimental Fruit Garden Sq No. 9, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan. The experimental plants grafted on rough lemon rootstock were spaced at about 7 m x 7 m, growing under similar agroclimatic conditions and received same cultural practices (Saleem *et al.*, 2004) during the period of investigations.

Plants were evaluated for uniformity of growth, fruit yield potential and possible disease incidence before the commencement of study. Thirty nine uniform plants with no apparent disease incidence were selected for the study in the form of a block. The soil analysis was done before low-biuret urea applications for checking the fertility status of

the soil by collecting representative composite soil samples from under the plants from four different sites. Soil analysis was done according to standard methods available at Farm Advisory Centre of Fauji Fertilizer Company (FAC-FFC) Lab., Jhang. Randomized Complete Block Design (RCBD) was applied with three replications, using single plant as a treatment unit.

Foliar spray of low-biuret urea: Aqueous solution (2%) of Low-biuret urea (LBU) was applied as foliar spray onto the whole plant to run off stage during the months of October, November and December in the year 2004, when fruit of previous season was on tree and its impact was studied on next year crop during 2005. The treatments were T_0 = Control; T1 = Foliar Spray of 2% LBU on 15th October 2004; T2 = Foliar Spray of 2% LBU on 15th November 2004 and T3 = Foliar Spray of 2% LBU on 15th December 2004

Fruit yield and grading: Fruit was counted on the plants on 18th October, 2005 (treatment and replication wise) and yield was recorded as number of fruit/plant. Fruits were harvested during Ist week of December 2005 and visually graded into three categories, based on fruit size, smoothness, blemishes, color break etc. Three grading categories were Grade-I - good marketable fruit; Grade-II - oversized or undersized fruit and Grade-III -rough surface or blemished fruit

Fruit sampling and physical analysis: Samples of 30 representative fruits were collected randomly from all sides of each plant and average fruit weight (g) was calculated. The fruit diameter (mm) was measured using a vernier caliper. The fruits were washed under tap water, dried under shade, cut into two halves, and seeds were extracted from each of 10 fruits separately to record seed number and weight (g)/fruit while peel thickness (mm) was measured using a vernier caliper. After peeling, juice was extracted in a beaker to get average fruit juice weight (g)/fruit, while peel and pulp was also weighed (g) separately and the quantities of all these were expressed on percentage basis. Some of the fruit juice was kept in sealed plastic container for biochemical analysis immediately. Hedonic scale rating for pulp colour, taste, appearance and colour break of fruit was done by the method described by Peryam & Pilgrim (1957).

Biochemical analysis of fruit: The fruit juice quality analysis including total soluble solids (TSS), acidity, TSS/acidity ratio, vitamin C, and sugar contents were performed following standard procedures (Saleem *et al.*, 2008) at the Pomology Laboratory Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.

Statistical analysis: The data collected for different parameters was statistical analyzed by using computer software MSTAT-C (Freed & Scott, 1986), while DMR test was used to separate the treatment means at 5% level of probability.

Results and Discussion

Fruit yield and grading: The results regarding fruit yield and grading at the time of fruit harvest are presented in Table-1. It is apparent that 2% LBU treatments significantly increased the total yield per plant as compared to control. Fruit yield was maximum (689.70 fruit/plant) when foliar spray of LBU was applied on 15th November, 2004. The

treatments applied on either 15th October or 15th December in 2004 were at par with one another, whereas less number of fruits per plant (340) were recorded in control (Table-1). Foliar treatments of low-biuret urea applied on 15th October or 15th November, 2004 produced maximum (64.67 & 65.58 % respectively) grade-I fruits per plant as compared to treatment applied on 15th December 2004 or control. However, none of the treatments showed any impact on grade-III fruits per plant.

It is reported that better yield of good quality citrus fruit can be achieved by the adequate supply of nitrogen at a critical stage of fruit initiation and development (Jackson, 1991; Davies & Albrigo, 1994; Tucker *et al*., 1995; Alva *et al*., 2006). On the other hand, low fruit yield was observed with low leaf nitrogen in citrus plants during flowering and fruit setting regardless of the levels during the remaining fruiting cycle (Jones & Embleton, 1954). Reduced initial fruit drop (data not shown) because of foliar application of LBU increased total production of 'Blood Red' sweet orange. It indicated that nitrogen applications improved the general health and vigor of plants that also improved the final yield of plants. These findings are in line with the findings of Azzony *et al*., (1970), Franciosi (1985) and Lovatt *et al*., (1992) and Sattar (1999), in which they reported an increase in yield through foliar application of nitrogen on citrus plants. However, the findings of Pedrera & Hernandez (1984) were in contrast to the above findings and stated that there is very week correlation between foliar nitrogen applications and citrus fruit yield.

Increase in grade-I fruits per plant may be due to increase in overall nitrogen contents of 'Blood Red' sweet orange as a result of foliar application of low-biuret urea that enhanced the fruit quality because of improved health of plants. Our results are in accordance with the findings of Wright & Pena (2002) in which they reported improvement in fruit size and grade with the application of low-biuret urea on 'Washington Navel' sweet oranges.

Physical analysis of fruit: The data regarding seed quantity and quality is presented in Table-1. The number of seeds per fruit showed significant differences among treatments. Greater number of seeds per fruit (9.97) was observed in fruits with control treatment which was not statically different in LBU foliar application either applied in December, 2004 (9.80) or in October, 2004 (9.40). The lowest number of seeds per fruit (5.60) was observed in October, 2004 treatment. Seed weight was greater in all the LBU foliar applications than control. The heaviest (1.63 g) seeds were found in fruits treated in the month of October, 2004 and were statistically at par (1.47 g) with the treatment applied in December, 2004, however, lighter weight (0.60 g) seeds were in control. Seed health was better in all the LBU foliar applications than control. On the other hand, LBU foliar applications significantly reduced seed abortion compared with control. Highest seed abortion (50.86 %) was observed in control and 12.56, 11.14 and 10.60 % seed abortion was recorded when LBU foliar treatments were applied in the months of October, December and November respectively.

Appearance of fruit, peel color, pulp color and taste were tested and the data were analyzed as presented in Table-1. The fruits on plants treated with LBU foliar applications were having significantly smoother peel as compared to control having lowest score (3.1). The score for peel smoothness was 4.26, 4.05 and 3.94 for foliar applications in November, October and December respectively, and the treatments were statistically at par with one another. Foliar applications of LBU also significant improved

peel color as compared to control. The highest score of peel color was 4.40 with the foliar LBU application in December, 2004 and lowest score of 2.23 in control treatment. November and October treatments were mediocre with a score of 3.87 and 3.52 respectively. Pulp color was also improved with the LBU foliar applications. Better pulp color was developed by foliar applications in November and December with a score of 4.18 and 3.87 respectively, and was statistically at par with one another. Lowest pulp color score of 2.98 was observed in control. Fruit taste has the same trend as peel color. Better juice taste score (4.00) was attained with the LBU foliar application in the month of December as compared to control (2.26). Foliar applications in the month of October and November attained 3.58 and 3.46 score for taste respectively and were mediocre and statistically equal.

Citrus fruit is sold at retailer end by weight hence it is very important factor towards fruit yield and quality. The results pertaining to fruit weight and diameter were significantly affected by foliar spray of low-biuret urea in winter. The increment in fruit weight in control could be attributed to the less number of fruit per tree. Smaller number of fruit may get more metabolites and plant food reserves. Therefore, low yield was positively correlated with more weight and diameter of fruit (Alva *et al*., 2006). Our results do not coincide with the findings of Wright & Pena (2002) who reported that fruit size was improved by application of low-biuret urea on 'Washington Navel' sweet oranges. Samra *et al*. (1977) reported that urea applied @ 4% to fully grown mango trees (5 Kg ha^{-1}) at full bloom stage significantly increased number of fruit and fruit weight but maturity was delayed with considerable increase in leaf nitrogen, which is again not in accordance with our results.

Among the physical parameters examined were average fruit weight, fruit diameter, peel thickness and quantity of peel, pulp and juice. Average number of seeds, seed weight per fruit and healthy and aborted seeds per fruit were recorded (Table 2). Fruit weight was low in all LBU foliar application as compared to control (195.70 g), however; LBU foliar application in November, 2004, gained the lowest fruit weight (108.30 g). Other treatments were mediocre but at par with one another. Similar trend was observed in case of fruit diameter. Fruit diameter was greatest (69.3 mm) in control and lowest (57.0 mm) in foliar application of LBU in November, 2004; however, this treatment was statistically at par with the foliar application in October, 2004. Peel thickness was greatest (5.20 mm) in fruits treated with LBU foliar application in December, 2004 and lowest (2.70 mm) in November, 2004 treated plants. The data for foliar application in October, 2004, and control was statistically at par with one another. On the other hand, all the treatments were non-significant when data was converted to peel percentage. Pulp percentage was greater (20.89 %) in fruits when LBU foliar application was done in the month of December, 2004, but, this treatment was statistically at par with control (17.83 %) and LBU application in the month of October, 2004 (20.41 %). The lowest pulp percentage (16.97 %) was with the foliar LBU application in the month of November, 2004, but, statistically was not different than control or October, 2004, treatment. Juice percentage ranged from 41% - 47 % of the total fruit weight and there was no significant difference among different treatments.

Peel thickness was significantly greater in fruits when LBU was applied as a foliar spray in the month of December, 2004, whereas it was decreased in the treatment applied in November, 2004 than control. It is an established fact that nitrogen application increases peel thickness (Rajput & Haribabu, 1985). According to Sattar (1999), the

Table 1: Effect of winter application of low-biuret urea on fruit set, yield and physical quality characters of 'Blood Red' sweet Orange fruit

Treatments	Yield Fruit No./Tree	Fruit Grading (%)		Organoleptic Evaluation			
		Grade-I	Grade-III	Appearance (Score)	Peel Colour (Score)	Pulp Colour (Score)	Taste (Score)
Control	340.70c	37.48b	17.84	3.10b	2.23c	2.98b	2.26c
October	589.00b	64.67a	11.33	4.05a	3.52b	3.66ab	3.58ab
November	689.70a	65.58a	11.14	4.26a	3.87b	4.18a	3.46b
December	543.30b	54.70ab	9.54	3.94a	4.40a	3.87a	4.00a
	*	*	N.S	*	*	*	*
Seed Quantity and Quality							
	Total Seed/Fruit	**Seed Wt. /Fruit (g)**	**Healthy Seeds (%)**	**Aborted Seeds (%)**			
Control	9.97a	0.60c	48.14b	50.86a			
October	9.40a	1.63a	87.44a	12.56b			
November	5.60b	0.90b	89.42a	10.60b			
December	9.80a	1.47a	88.68a	11.14b			
	*	*	*	*			

N.S=Non Significant, *= Figures sharing the same letters in the same column differ significantly at $P \leq 0.05$

Table 2: Effect of winter application of low-biuret urea on physical biochemical characters of 'Blood Red' sweet orange fruit

Treatments	Physical Characters					
	Fruit Weight (g)	Fruit Dia (mm)	Peel Thickness (mm)	Peel (%)	Pulp (%)	Juice (%)
Control	195.70a	69.3a	4.33b	40.12	17.83ab	41.05
October	133.70b	60.1bc	3.80b	32.40	20.41ab	47.19
November	108.30c	57.0c	2.70c	38.57	16.97b	44.47
December	134.70b	63.5b	5.20a	32.83	20.89a	46.28
	*	*	*	N.S	*	N.S
	Biochemical Characters						
	TSS (%)	**Total Sugars (%)**	**R. Sugars (%)**	**N.R.Sugars (%)**	**Acidity (%)**	**Vit. C (mg/100ml)**	**TSS/Acidity**
Control	8.30c	4.943c	2.55b	2.26c	0.759b	43.01c	10.93b
October	10.35ab	6.26b	2.89ab	3.20b	0.852a	46.84b	12.14ab
November	11.05a	7.13a	3.24a	3.73a	0.847a	51.58a	13.04a
December	9.61b	6.01b	2.72ab	3.12b	0.870a	47.74b	11.04b
	*	*	*	*	*	*	*

N.S=Non Significant, *= Figures sharing the same letters in the same column differ significantly at $P \leq 0.05$R=Reducing, N.R=Non reducing

peel thickness should be more in the heavier fruit (control) but in our study the thickest peel was found in December treatments having maximum leaf nitrogen contents (Data not shown), which is in accordance with the reports of Rajput & Haribabu (1985). However, in November treatment although leaf nitrogen difference was non significant as compared to December (Data not shown), least peel thickness in November treatment could be attributed to more number of fruit as well as reduced fruit size.

The results pertaining to internal physical characters (Table 2) revealed that foliar application of LBU had no significant effect on peel and juice quantity, while significant differences were found in pulp percentage among different treatments without any clear cut trend. All the differences in internal physical characters were interrelated. It was reported that juice percentage of fruits was not affected by increased doses of nitrogen (Jones & Parker, 1949; Rajput & Haribabu, 1985; Nasir *et al*., 1989). In contrast, Singh & Singh (1981) reported that foliar spray of nitrogen increased fruit juice contents in citrus fruits. Higher rates of nitrogen increased the peel weight in citrus (Azzony *et al*., 1970; Dasberg *et al*., 1983; Mann & Sandhu, 1988), but it was not confirmed by our results. El-Otmani *et al*. (2004) reported that during 'off year' the urea treated trees of 'Washington Navel' sweet orange had more fruit juice compared to control.

Total number of seeds per fruit and seed health was significantly affected by all LBU foliar treatments (Teble-1). It is apparent that with the improvement of seed health/vigor seed abortion was reduced, hence, this potential of LBU can be employed in producing good quality seeds in citrus rootstocks, which is growing need of citrus industry. Higher seed contents in edible varieties are however, not welcomed, hence, the foliar application of LBU did not prove beneficial in this aspect of fruit quality. The improvement in seed health may be attributed to improved nitrogen metabolism that might be involved in fertilization, seed formation, growth and development. Our results in this regard are in agreement with Hussain & Ali (1972) and Jeelani (1994) who reported that there was appreciable change in seed number by fertilizer application.

Our results regarding hedonic scale rating of smoothness of fruit, peel color, taste and pulp color indicated the significant effect of foliar treatments of LBU. All the treatments contributed to enhance the fruit quality. Fruit taste depends upon the blend of acidity and sugars and is according to above mentioned results of biochemical analysis (TSS/Acidity ratio). However, color break of peel was enhanced by foliar treatments, but previous reports indicate that any factor that enhance the vigor of the plant, delays the peel colour development and plants receiving excessive nitrogen tend to have poor peel colour (Davies & Albrigo, 1994). It may be attributed to the fact that the experimental trees were under stress with very less leaf age and due to the treatments of urea, the leaf age was increased that helped provide better and balanced quantity of metabolites, resulting in better fruit growth and development and improved fruit quality. The leaf nitrogen of 'Blood Red' sweet oranges indicated that there was increase in levels with the foliar spray of the low-biuret urea which ultimately enhanced the quality of fruit due to improved plant health and leaf life. Overall, foliar application of LBU in November, 2004, performed the best of all treatments with respect to fruit quality.

Biochemical analysis of fruit: The data pertaining to TSS showed that the treatments significantly increased total soluble solids in fruit juice as compared to control (Table-2). The greater value of TSS (11.05 %) was observed in fruits which received LBU foliar application in November, 2004, than control in which TSS value was 8.30%. The other

treatments were mediocre. TSS/Acidity ratio was greater (13.04) with LBU foliar application in November, 2004 and was statistically at par with the treatment in October, 2004. On the other hand, foliar treatment in October, 2004 was at par (12.14) with rest of the treatments having 11.04 and 10.93 TSS/Acidity ratio for December, 2004 foliar LBU application and control, respectively. Vitamin C in fruits was significantly affected by different LBU foliar applications. The greater amount of vitamin C (51.58 mg/100ml) was recorded in foliar applications in November and lowest (43.01 mg/100ml) in control. The mediocre results were found with other treatment. Total sugars were increased with the LBU foliar applications as compared to control. The greater amount of total sugars (7.13 %) was found in the foliar application in November, 2004 and the least amount (4.94%) in control. Other treatments were in the middle and at par with one another statistically. Similar trend was found in case of non-reducing sugars. The greater amount of non-reducing sugars (3.73 %) was found in the foliar application in November, 2004 and the least amount (2.26 %) in control. Other treatments were in the middle and statistically at par with one another.

The results of biochemical analysis revealed that most of the parameters were improved when LBU was used as foliar spray as compared to control. Fruit quality enhancement with the application LBU may be attributed to improvement of general plant health and vigor and retention of previous year leaves which led to healthy flower formation followed by better fruit formation, growth and development. The better fruit TSS, sugars profiles, color and taste in our experimental plants confirmed the findings of Krishna *et al*. (1979), Baldry *et al*. (1984), Ahmed *et al*. (1988) and Nath and Mohan (1995), who reported that highest nitrogen rates resulted in highest TSS contents in different varieties of citrus. However, Obreza & Rouse (2006) reported that fruit juice quality and TSS were not generally affected by N in 'Hamlin' sweet orange. Likewise, Embleton *et al*. (1978) found inconsistent effect of nitrogen on TSS of citrus fruit. Total soluble solids comprise of sugars, organic acids, proteins, vitamins and other soluble constituents with major portion of carbohydrates (70-80 %) which are mostly sugars (Erickson and Brannman, 1960). Therefore the response of sugars profile in fruit juice remained the same as in case of TSS.

Winter foliar application of LBU increased the contents of ascorbic acid significantly as compared to control. This trend of increment in vitamin C again may be due to the result of overall better quality including organic acid biosynthesis. Our results were not in accordance with Reuther & Smith (1952) and Smith *et al*. (1953), who observed that highest nitrogen application depressed vitamin C content of juice of 'Valencia' orange fruit. Similarly, these results do not match with the findings of Azzony *et al*. (1970) that foliar spray of urea to Navel orange plant did not significantly affect the vitamin C contents of fruits. Effects of nutrition, especially nitrogen, on fruit quality like TSS; Total Acids etc. are inconsistent (Davies & Albrigo, 1994). Wright & Pena (2002) reported improvement in fruit size and grade with application of LBU on 'Washington Navel' sweet oranges, however, there were non significant differences among treatments in case of juice (%,), TSS (%), TA, TSS: TA, pH and peel thickness (mm) during 2 years of experimentation. The range of vitamin C contents remained between 43.01 - 51.58 mg/100ml, as according to previous reports (Stewart & Klotz, 1947; Raza, 1997).

Conclusion: This study was conducted using 15 year-old, low productive 'Blood Red' orange plants to evaluate the effect of winter application of low-biuret urea (LBU) on

marketable fruit yield and quality. It was concluded that winter application of 2% LBU, improved the marketable fruit yield and quality of 'Blood Red' sweet orange. All the treatments produced better quality fruit with grade-I. Overall, the best results were found with LBU foliar application in the month of November, 2004. Hence, foliar application of LBU in winter may be recommended to enhance the quality production of sweet oranges, which may in turn be able to pave the way for their re-induction in Punjab citrus industry.

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