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Impact of Lipo-Chito-Oligosaccharides (LCO) as Foliar Spray on Soybean (*Glycine max* (L.) Merr.) Yield

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The bacterium to plant signal, lipo-chito-oligosaccharides (LCOs) or Nod factors induce cell division and enhance plant growth. In the present study LCO has been applied through foliar spray at two different stages (V_2), 20-25 DAS and 40-45 DAS (V_4). All the yield contributing parameters were increased by the foliar spray of LCO in soybean and the maximum yield was recorded in LCO @ 300 ml ha^{-1} at 20-25 DAS. The yield increased by 10.6 per cent at *kharif* and 14.3 per cent during *rabi* 2012. Correlation studies indicated that seed yield per hectare exhibited stable positive association *vis-a vis* number of flowers, pods per plant, fertility co-efficient, 100 grains weight and harvest index at different stages and seasons.

Key words: LCO, Soybean, Seasons, Correlation, Yield and Yield parameters

Lipo-chito-oligosacchrides (LCO) in general are capable of influencing plant growth and development. They are mainly secreted by *Rhizobia* spp and play a key role in the stimulation of nodules in legumes by activating signaling events of certain growth hormones, nutrients and important plant metabolism. LCO have both direct and indirect effects on various physiological processes. They provide minerals, biochemical substances and nutrients to the rhizosphere microbial population, carry the trace elements and growth regulators for stimulating plant growth.

LCO signal molecules are composed of three to five, 1-4 â linked acetylglucosamine residues with the N-acetyl group of terminal non-reducing sugar replaced by an acyl chain. However, various modifications of the basic structure are possible and these, at least in part, determine the host specificity of rhizobia (Schultze *et al*., 1992).

LCOs at very low concentration, initiate cell division at distinct sites in the root (Lerouge *et al*., 1990; Truchet *et al*., 1991). Possibly, these signals affect the regulation of the plant cell cycle and evidence is accumulating that LCOs play a general role as plant growth regulators (Schmidt *et al*., 1999). LCOs enhance photosynthesis and plant growth, and help to ensure that corn and soybean crops realize their performance potential. When applied on the foliar surface of corn or soybean, the LCO signal molecule provides an increase in photosynthesis and sugar production, which may enhance plant growth and improve overall crop performance.

Number of flowers produced, flowering duration and percentage of pod set are very important traits in determining pod yield (Patel *et al*., 1988). Excessive flower production and long flowering duration appear to be a persisting phenomenon that would act as an insurance against climatic and biotic factors. Flower production is reduced by temperature below 20°C and above 40°C in soybean (Van Schaik and Probst, 1958). With these background, the present study has been taken up to elucidate the association of LCOs on yield and its parameters in soybean, over two different seasons.

Materials and Methods

Field trials

The field experiments were conducted during winter (January, 2012) and summer (April, 2012) in a randomized block design (RBD) with three replications at wet land farm of Tamil Nadu Agricultural University, Coimbatore. The plant density in the field was approximately 3,33,000 ha^{-1}. Other agronomic practices were carried out as mentioned in crop production guide (CPG, 2005). Plants in the field received the foliar application of LCOs at a dosage of 150 ml ha^{-1}, 300 ml ha^{-1} and 600 ml ha^{-1} at two different stages *i.e.,*V_2 (20-25 DAS) and V_4 (40-45 DAS).

Chemical composition of LCOs

Ratchet$_{TM}$ is a LCO promoter compound, which is manufactured by EMD Crop Biosciences.It contains a minimum of 4 x 10^{-7} per cent lipo-chito oligosaccharide (LCO) in an aqueous carrier, which has been formulated for maize and soybean as foliar application. This product contains only components that are naturally occurring in soil and are biodegradable. Ratchet is compatible with most of the post emergence applied products such as agrochemicals to get an optimal result, it has to be

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applied between V2 (early vegetative stage – 20 DAS) and V6 (late vegetative stage 50 DAS) of the crops.

Statistical analysis

The data collected on different characters from the field were statistically analysed as suggested by Gomez and Gomez (1992) and the least significant difference (LSD) test was used to detect critical differences at 5% level among treatment means.

Results and Discussion

Number of flowers and pods, fertility co-efficient and 100 grains weight were increased due to the application of LCO. In LCO treated plants, flower dropping was reduced consequently, and the number of pods per plant was found to be increased. Significant variation was observed among the seasons and the maximum number of flowers was found in summer, when compared to winter.

Table 1. Impact of LCO on number of flowers and pods in soybean

Treatments	No. of flowers				No. of pods			
	Winter		Summer		Winter		Summer	
	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)
T_1 - Control	146.70$_{d}$	146.70$_{d}$	164.10$_{d}$	164.10$_{d}$	75.14$_{d}$	75.14$_{d}$	84.08$_{d}$	84.08$_{d}$
T_2 - LCO @ 150 ml ha^{-1}	153.50$_{c}$	169.40$_{c}$	171.80$_{c}$	189.60$_{c}$	93.66$_{c}$	105.30$_{c}$	104.81$_{c}$	117.84$_{c}$
T_3 - LCO @ 300 ml ha^{-1}	172.80$_{a}$	175.10$_{b}$	193.40$_{a}$	195.90$_{b}$	108.60$_{a}$	112.42$_{b}$	121.53$_{a}$	125.81$_{b}$
T_4 - LCO @ 600 ml ha^{-1}	167.10$_{b}$	177.40$_{a}$	187.00$_{b}$	198.50$_{a}$	104.46$_{b}$	117.92$_{a}$	116.90$_{b}$	131.96$_{a}$

Winter: January 2012 Summer: April 2012

LCO application showed significant effect on plant hormones such as GA_3 and IAA, which are known to help in preventing flower abortion and increasing fruit set. The increase in yield over control was around 21 per cent in both the season and stages. Similar result was noticed by Atti *et al*. (2005) in soybean and Chen *et al*. (2007) in tomato. Application of LCO as foliar spray promoted pod setting. LCO application at V_2 stage @ 300 ml ha^{-1}

Table 2. Impact of LCO on fertility coefficient and 100 grains weight in soybean

Treatments	Fertility coefficient (%)				100 grains weight (g)			
	Winter		Summer		Winter		Summer	
	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)
T_1 - Control	51.20d	51.20d	51.22c	51.22d	11.63d	11.63d	12.29d	12.29d
T_2 - LCO @ 150 ml ha^{-1}	60.99c	62.14c	60.98b	62.13c	12.77c	12.65c	13.50c	13.38c
T_3 - LCO @ 300 ml ha^{-1}	62.82a	64.18b	62.81a	64.20b	13.05b	13.68a	13.80b	14.46a
T_4 - LCO @ 600 ml ha^{-1}	62.49b	66.44a	62.49a	66.45a	13.40a	13.11b	14.17a	13.86b

Winter: January 2012 Summer: April 2012

(T_3) increased the pod number by 44.5 per cent during winter season and T_4 (LCO @ 600 ml ha^{-1} during V_4 stage) has increased pod number upto 56.9 per cent during summer (Table 1).

The optimum foliar application of LCO was found to be 150 to 600 ml ha^{-1}. These dosages were

Table 3. Impact of LCO on yield and harvest index in soybean

Treatments	Grain (kg ha^{-1})				Biomass (kg ha^{-1})				Harvest index (%)			
	Winter		Summer		Winter		Summer		Winter		Summer	
	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)	V_2 (20 DAS)	V_4 (40 DAS)
T_1 - Control	905.03$_{c}$	905.03$_{c}$	906.60$_{d}$	906.60$_{d}$	2851.29$_{b}$	2851.29$_{b}$	2842.14$_{d}$	2842.14$_{d}$	31.75$_{d}$	31.75$_{d}$	31.89$_{c}$	31.89$_{d}$
T_2 - LCO @ 150 ml ha^{-1}	941.69$_{b}$	965.27$_{b}$	995.40$_{c}$	1020.30$_{c}$	2837.37$_{b}$	2887.53$_{b}$	2951.17$_{c}$	3002.73$_{c}$	33.18$_{c}$	33.42$_{c}$	33.72$_{b}$	33.97$_{a}$
T_3 - LCO @ 300 ml ha^{-1}	948.43$_{ab}$	980.43$_{ab}$	1002.50$_{b}$	1036.30$_{b}$	2851.66$_{b}$	2919.77$_{b}$	2966.06$_{b}$	3068.79$_{b}$	33.25$_{b}$	33.57$_{b}$	33.79$_{b}$	33.76$_{b}$
T_4 - LCO @ 600 ml ha^{-1}	966.96$_{a}$	998.96$_{a}$	1022.10$_{a}$	1055.90$_{a}$	2891.72$_{a}$	3052.24$_{a}$	3007.14$_{a}$	3173.84$_{a}$	33.43$_{a}$	32.72$_{a}$	33.98$_{a}$	33.26$_{c}$

Winter: January 2012 Summer: April 2012

applied at two different stages of the crop for better result. The present studies indicated that the application of LCO at later stage (V_4) had increased the yield of soybean crop upto 16 per cent (Table 2). LCO helps in maintaining the higher chlorophyll content of the leaf, inturn increasing the leaf area and duration. The enhancement in yield may be due to the increase in photosynthetic rate of the crop.

This results are also supported by the increase in root length, which might have helped the plants to uptake more nutrients, especially nitrogen resulting in the maintenance of greenness of the leaf, ultimately enhancing photosynthetic rate. LCO acts similar to that of cytokinin, which helps in translocation of photoassimilates from the source (leaf) to the sink (kernel/pod), by delaying the senescence of the leaves (stay green). The increase in yield due to the application of LCO was reported earlier by Atti *et al*. (2005) in soybean; Chen *et al.* (2007) in tomato and Khan (2003) in corn. Dry matter seems to be non significant even after the application of LCO (Table 3).

Pod number is a major yield determining factor in plants that belong to Fabaceae. Seasons had also showed significant influence on the number of pods per plant. Higher number of pods per plant was recorded in summer season in pigeon pea (Anil kumar *et al*., 2004); soybean (Kausale *et al*., 2006); guar (Lakshmi Kalyani and Maheswara Reddy, 2007) and mung bean (Guriqbal Singh and Sekhon, 2007).

Table 4. Correlation coefficients of different characters in soybean at two stages of crop growth

	No. of flowers		No. of pods		Fertility co-efficient (%)		100 grains weight (g)		Grain yield (kg ha^{-1})		Biomass (kg ha^{-1})		Harvest Index (%)	
	V_2	V_4	V_2	V_4	V_2	V_4	V_2	V_4	V_2	V_4	V_2	V_4	V_2	V_4
No. of flowers	1.00	1.00												
No. of pods	0.95*	0.91*	1.00	1.00										
Fertility co-efficient (%)	0.83*	0.99*	0.96*	0.89*	1.00	1.00								
100 grains weight (g)	0.84*	0.92*	0.95*	0.91*	0.97*	0.89*	1.00	1.00						
Grain yield (kg ha^{-1})	0.80*	0.91*	0.93*	0.99*	0.97*	1.00*	0.99*	0.89*	1.00	1.00				
Biomass (kg ha^{-1})	0.79*	0.88*	0.87*	0.91*	0.87*	0.91*	0.97*	0.74*	0.96*	0.91*	1.00	1.00		
Harvest Index (%)	0.77*	0.84*	0.93*	0.81*	0.99*	0.81*	0.98*	0.82*	0.99*	0.81*	0.89*	0.49	1.00	1.00

* Significant at 5 per cent level; V_2 – Early vegetative stage (20 – 25 DAS); V_4 – Late vegetative stage (40 – 45 DAS)

Present findings are also in line with the earlier reports of Lalit Kumar *et al*. (2009) and Naeem *et al*. (2009). Enhancement in yield attributes ultimately might have culminated into pod yield as reported by Naeem *et al*. (2009).Correlation of yield and yield related parameters exhibited individual or combination effects over seasons. It was further observed that yield parameters such as number of flowers and pods, fertility co-efficient and 100 grains weight have showed positive and significant association with grain yield and harvest index in combination with seasons (Table 4).

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