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Manipulations of source sink relationships through mepiquat chloride for enhancing cotton productivity and monetary returns in north western India

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ABSTRACT : Field experiments were conducted during *kharif* 2014 and 2015 at PAU, Regional Station, Faridkot to manipulate source sink relationships in American cotton through application of mepiquat chloride. Highest seed cotton yield (2976 kg/ha) was recorded with application of mepiquat chloride @1500 ml/ha primarily due to improved boll weight (3.92g) and bolls/plant (53.2). Consequently, highest net returns of Rs 83405/ha and B:C ratio (2.0) was recorded with the application of mepiquat chloride @1500 ml/ha indicative of its monetary benefits. mepiquat chloride not only suppressed the height of cotton plants significantly but also resulted into the higher yield attributes due to favorable source sink relationships over control. Therefore, for maximizing the monetary returns, farmers should opt for mepiquat chloride application @1500 ml/ha {@500 ml/ha + 500ml/ha+ 500ml/ha at 60, 75 and 90 DAS} should be considered a useful production practice for enhancing cotton yield under semi arid conditions of north western India.

Key words : American cotton, bolls, monopods, seed cotton yield and sympods

Cotton is one of the important cash crops in world. Cotton crop attains excessive vegetative growth mainly due to high soil fertility; coincidence of vegetative growth period with rainy season coupled with high humidity. Thick crop canopy prevents penetration of light besides shading of bolls and utilization of plant energy on the formation of vegetative stature which results in shedding of flower buds, flowers and immature bolls. Excessive vegetative growth often occurs at the expense of reproductive growth and a large fraction of squares and small bolls on the lower sympods either shed or open poorly resulting in low yield. Cotton plants must have a harmonic balance between vegetative and reproductive growth for adequate photosynthates supply for healthy boll development leading to better productivity. Shekar *et al.,* (2015) reported that the use of chloro mepiquat chloride increases the N uptake resulting into higher seed cotton yield. Under extreme cases, rotting of lower bolls also occurs. The loss of reproductive structures alters the physiological growth and development of the plant by redirecting assimilates which normally are incorporated into these abscised organs to other plant parts. Most source sink research has focused on leaf boll relationships (harmonic balance) with little study of vegetative storage reserves. Gwathmey and Clement (2010) reported that source sink balance can be altered by using plant growth regulator such as mepiquat chloride (MC). The best way to prevent excessive vegetative growth is to manage for early and high fruit set. If early fruit are not set, the crop may compensate by setting fruit at higher nodes and

at outer fruiting positions leading to delayed crop maturity. Growth retardants like mepiquat chloride (MC) and 2,3,5 tri iodo benzoic (TIBA) are known to reduce inter nodal length, thereby, reducing plant height and stimulating the translocation of photosynthesis towards reproductive sinks (developing cotton bolls), all of which result in higher yields. Plant growth regulators (PGRs) may enhance yield by increasing the retention of photosynthates into developing bolls. PGRs have been widely used in developed nations for increasing cotton production by adjusting plant growth and to improve lint yield and fiber quality. Mepiquat chloride (MC) is used in cotton production across the globe to control plant growth and maximize yield and quality. Application of MC at squaring stage or at both squaring and flowering stages significantly improved cotton quality parameters like fiber length (1.7%) and fiber strength (2.8%) without significant loss of yields (Ren *et al.*, 2013). At present, no study is available that shows the quantitative effects of mepiquat chloride (application rate and time of application) on yield dynamics of American cotton in this region and their monetary evaluation. Farmer's also seek information on cotton response to growth retardants and their field utility. Moreover, with ongoing new product testing/ registrations and consequently much sought after mechanization required for cotton picking, this aspect is gaining importance. Ever growing labour shortage for picking will further aggravate the problem of cotton farmers and necessitates for lesser number of picking even if machine picking becomes reality in coming decade or so (Singh and Rathore, 2015). Generation of such information through field experimentation is therefore of prime importance. In the present work, it was intended to study the role of mepiquat chloride in manipulation of source sink relationships so as to have favorable influence on yield and yield attributes. Similarly, optimum dose and ideal time of application of mepiquat chloride for realizing high productivity and its economic viability was also evaluated.

MATERIALS AND METHODS

The experiment arranged in complete randomized block design was conducted during *kharif* 2014 and 2015 at Punjab Agricultural University, Regional Research Station, Faridkot which lies in Trans Gangetic agro climatic zone, representing the Indo Gangetic alluvial plains ($30^0$40'N and $74^0$44'E) of Punjab situated at 200 m above MSL. The experimental field during 2014 was having loamy sand soil, with slightly alkaline pH 8.7 , EC (0.24dS^{-m}), O.C (0.27 %), medium in available P (17.5 kg/ha) but high in available K (675kg/ha).During 2015, soil properties were slightly different *i.e.* loamy sand, near normal{ pH=8.4, EC=0.18 m mhos, OC% = 0.42}, P (kg/ha) =21.7, high in K (750 kg/ha) . *Bt* hybrid NCS 855 BGII was planted in first fortnight of May for both years on a well prepared field and grown by following the recommended package of practices except for the treatments under study. A planting geometry of 67.5 x 75 cm was maintained. During 2014, 7 treatments [*i.e.* Control; mepiquat chloride @1000 ml/ha,80-85 DAS, single application; mepiquat chloride @1250 ml/ ha,80-85 DAS , single application; mepiquat chloride @1500 ml/ha,80-85 DAS, single application; mepiquat chloride@1500 ml/ ha(@500 ml/ha + 500ml/ha+ 500ml/ha at 60,75 and 90 DAS) 3 applications; mepiquat chloride @1750 ml/ha (500 ml/ha + 625ml/ha + 625ml/ ha at 60,75 and 90 DAS) 3 applications and detopping at 70-80DAS] were studied but 8 treatments were evaluated during 2015.After evaluating the yield data of 2014, an additional

treatment *i.e.* mepiquat chloride @1500 ml/ha (750 ml/ha + 750 ml/ha at 75 and 90 DAS; 2 applications) was included in studies during 2015 for comparison with other treatments having same dosage because of labour saving. The chemical mepiquat chloride (5% w/w) was mixed with water (@200 L/ha) and delivered uniformly using a knapsack sprayer. Production cost was calculated by adding cost of all the fixed inputs. Monetary parameters were calculated on the basis of prevailing market price of inputs and seed cotton. The data were analyzed statistically using *SAS Proc* to test the significance. Since number of treatments during both years was different, hence mean of values for both years have been used to discuss results.

RESULTS AND DISCUSSION

Effect of mepiquat chloride on growth, yield attributes and seed cotton yield : The data on various growth related parameters clearly indicated significant effect of mepiquat chloride on recorded parameters. At all application rates, mepiquat chloride was found to be effective in reducing the plant height over control, during both of the study years. Application of mepiquat chloride @1750 ml/ha (@500 ml/ha + 625ml/ha+ 625ml/ha at 60, 75 and 90 DAS) recorded statistically least plant height of 139.1 and 93.4 cm, for 2014 and 2015, respectively (Table 1). Mepiquat chloride treated plants were reported to be typically shorter, more compact and possessed a characteristically darker green color than untreated plants. A similar trend as that of height was also recorded for monopods per plant which decreased with application of mepiquat chloride. Ren *et al.,* (2013) also reported better canopy architecture with dwarf plants, short sympodia, smaller leaves and bigger bolls obtained by chemical regulation through mepiquat chloride. Interestingly, de topping at 70-80 DAS resulted in an increase of monopod/plant, though effect was significant during 2014 only. Shekar *et al.,* (2015) too reported the suppression of plant height with the use of chloro mepiquat chloride. The primary reason for reduced height in mepiquat chloride treated plants could due to the suppressed production of gibberellic acid, a hormone responsible for cell elongation. Mepiquat chloride @ 1500ml/ha (@500 ml/ha + 500ml/ha+ 500ml/ha at 60, 75 and 90 DAS) resulted in highest sympods/plant (31.3) followed by its single application @1500 ml/ha (28.2) at 80-85 DAS while the least number was observed under control (21.6). This clearly indicated that mepiquat chloride has been responsible for the improved lateral growth by retarding vertical height. Gwathey and Clement (2010) and Shekar *et al.,* (2015) also reported that mepiquat chloride can improve cotton productivity. However, we found that application of mepiquat chloride@1750ml/ha resulted in decline in sympods/plant as compared to its other levels of application during both the years which was clearly indicative of its deleterious effect at higher dose under test location. A reduction in biomass was observed by the all treatments of mepiquat chloride over control (165 q/ha) indicative of shifting of source sink relationships in treated plots (Table 1).

Among yield contributing parameters, bolls/plant was significantly affected with application of chemical during both years while boll weight varied significantly only during 2014.The highest bolls/plant (53.2) and boll weight (3.92g) was recorded with application of mepiquat chloride (@500 ml/ha + 500ml/ha+ 500ml/ha at 60, 75 and 90 DAS) while control recorded least value for boll/plant (37.8) as well as for boll weight (3.38 g) .This clearly indicated

Table 1. Effect of mepiquat chloride on growth and ancillary parameters of American cotton

Treatments	Dose	Plant height (cm)			Monopods/plant			Sympods/plant			Biomass (q/ha)			Plant stand/ha		
	(ml/ha)	2014	2015	**Mean**	2014	2015	**Mean**	2014	2015	**Mean**	2014	2015	**Mean**	2014	2015	**Mean**
Control		194.1	135.2	**164.7**	2.00	1.72	**1.9**	23.7	19.4	**21.6**	205	151	**178**	18615	18900	**18758**
Mepiquat chloride 1000, Single application at 80-85 DAS		162.5	115.0	**138.8**	1.66	1.47	**1.6**	30.1	23.0	**26.6**	180	132	**156**	18750	19200	**18975**
Mepiquat chloride 1250, Single application at 80-85 DAS		160.8	112.8	**136.8**	1.83	1.30	**1.6**	27.7	25.7	**26.7**	173	128	**151**	18279	18800	**18540**
Mepiquat chloride 1500, Single application at 80-85 DAS		149.1	106.8	**128.0**	1.50	1.22	**1.4**	28.1	28.2	**28.2**	142	119	**131**	19153	18200	**18677**
Mepiquat chloride 1500 (3 applications @500 ml/ha + 500ml /ha + 500ml/ha at 60,75 and 90 DAS)		146.6	108.7	**127.7**	1.89	1.15	**1.5**	30.1	32.5	**31.3**	191	133	**162**	18011	19300	**18656**
Mepiquat chloride 1750 (3 applications @500 ml/ha + 625ml /ha+ 625ml/ha at 60, 75 and 90 DAS)		139.1	93.4	**116.3**	1.83	0.83	**1.3**	26.3	17.5	**21.9**	180	126	**153**	18414	19500	**18957**
De-topping at 70-80 DAS		135.0	103.8	**119.4**	2.66	2.07	**2.4**	28.0	24.9	**26.5**	141	94	**117**	18145	18100	**18123**
Mepiquat chloride 1500 (2 applications @750 ml/ha + 750 ml/ha at 75 and 90 DAS)		-	101.4	**-**	-	0.94	**-**	-	19.0	**-**	-	127	**-**	-	18200	**-**
CD (p=0.05)		12.0	9.8	-	0.56	0.34	-	4.0	3.9	-	28.3	16.4	-	NS	NS	-

Table 2. Effect of mepiquat chloride on yield attributes and seed cotton yield

Treatments	Dose (ml/ha)	Bolls/plant			Boll weight (g)			Seed cotton yield (kg/ha)		
		2014	2015	**Mean**	2014	2015	**Mean**	2014	2015	**Mean**
Control		42.1	33.4	**37.8**	3.33	3.42	**3.38**	2524	1732	**2128**
Mepiquat chloride 1250, Single application at 80-85 DAS		49.9	43.2	**46.6**	3.56	3.81	**3.69**	3151	2201	**2676**
Mepiquat chloride 1500, Single application at 80-85 DAS		45.5	46.0	**45.8**	3.50	3.97	**3.74**	2885	2315	**2600**
Mepiquat chloride 1500 (3 applications @500 ml/ha + 500ml /ha + 500ml/ha at 60,75 and 90 DAS)		57.6	48.7	**53.2**	3.70	4.13	**3.92**	3422	2529	**2976**
Mepiquat chloride 1750 (3 applications @500 ml/ha + 625ml /ha+ 625ml/ha at 60, 75 and 90 DAS)		50.4	36.1	**43.3**	3.36	3.30	**3.33**	3125	1816	**2471**
De-topping at 70-80 DAS		46.6	40.0	**43.3**	3.43	3.74	**3.59**	3049	2074	**2562**
Mepiquat chloride 1500 (2 applications @750 ml/ha + 750 ml/ha at 75 and 90 DAS)		-	50.0	**-**	-	3.87	**-**	-	2455	**-**
CD (p=0.05)		10.4	5.9	-	NS	0.34	-	474	286	-

that all treatments of mepiquat chloride favored source sink relationships towards the improved seed cotton yield (Table 2). Mean of 2 years data revealed highest seed cotton yield (2976 kg/ha) with application of mepiquat chloride @ 1500 ml/ha (500 ml/ha + 500ml/ha+ 500ml/ha at 60, 75 and 90 DAS) followed by 2676 kg seed cotton yield under its single application @1250 ml/ha at 80-85 DAS (Table 2).Control treatment recorded significantly reduced yield of 2524 kg and 1732 kg seed cotton as compared to yield under application of mepiquat chloride @ 1500 ml/ha (500 ml/ha + 500ml/ha+ 500ml/ha at 60, 75 and 90 DAS) during 2014 and 2015, respectively. Similarly, non significant differences were observed among test treatments for GOT, lint

Table 3. Effect of mepiquat chloride on GOT and lint parameters

Treatments	Dose (ml/ha)	GOT (%)			Lint yield (kg/ha)			Seed yield (kg/ha)		
		2014	2015	**Mean**	2014	2015	**Mean**	2014	2015	**Mean**
Control		37.0	34.6	**35.8**	934.7	598.9	**766.8**	1589.4	1133.0	**1361.2**
Mepiquat chloride 1000, Single application at 80-85 DAS		36.8	33.7	**35.3**	1061.4	683.7	**872.6**	1816.2	1344.3	**1580.3**
Mepiquat chloride 1250, Single application at 80-85 DAS		37.0	32.7	**34.9**	1164.1	720.7	**942.4**	1987.6	1480.2	**1733.9**
Mepiquat chloride 1500, Single application at 80-85 DAS		37.6	33.1	**35.4**	1085.4	767.3	**926.4**	1800.3	1547.7	**1674.0**
Mepiquat chloride 1500 (3 applications @500 ml/ha + 500ml /ha + 500ml/ha at 60,75 and 90 DAS)		36.6	33.3	**35.0**	1255.0	842.3	**1048.7**	2167.0	1686.6	**1926.8**
Mepiquat chloride 1750 (3 applications @500 ml/ha + 625ml /ha+ 625ml/ha at 60, 75 and 90 DAS)		35.3	31.7	**33.5**	1105.1	578.6	**841.9**	2019.8	1237.4	**1628.6**
De-topping at 70-80 DAS		36.5	31.9	**34.2**	1113.1	662.7	**887.9**	1936.5	1411.3	**1673.9**
Mepiquat chloride 1500 (2 applications @750 ml/ha + 750 ml/ha at 75 and 90 DAS)		-	32.9	**-**	-	807.1	**-**	-	1647.8	**-**
CD (p=0.05)		NS	1.21	-	NS	96.4	-	296.6	194.7	-

yield for year 2014 only but during 2015, parameters such as GOT, lint yield as well as seed yield were statistically affected (Table 3) probably due to reduced ginning outturn values for the later year. Numerically reduced value of GOT (%) as well as lint yield with mepiquat chloride @ 1750 ml/ha (500 ml/ha + 625ml/ha+ 625ml/ha at 60, 75 and 90 DAS) revealed that source sink relationships were negatively affected with higher dose of chemical. This clearly indicated that application of mepiquat chloride @ 1500 ml/ha (500 ml/ha + 500ml/ha+ 500ml/ha at 60, 75 and 90 DAS) was the best combination to get higher yield and yield attributes. Our results elucidated that application of mepiquat chloride @ 1500 ml/ha (500 ml/ha + 500ml/ha+ 500ml/ha at 60, 75 and 90 DAS) has potential to improve yield while keeping vegetative and reproductive growth in harmony.

Effect of mepiquat chloride on monetary parameters : The data clearly indicated significant effect of treatments on various monetary parameters. Among the chemical treatments, the cost of chemical and man power involved in its application as well as more picking charges due to increased seed cotton yield, significantly raised the total cost of cultivation over control (Table 4).Significantly higher net returns (Rs 83045/ha) and B: C ratio (2.0) were recorded with application of mepiquat chloride @ 1500 ml/ha as compared to control. Singh *et al.,* (2015) has also reported beneficial effect of various plant growth regulators in improving the seed cotton yield as compared to control conditions.This was indicative of favorable effect of mepiquat chloride @ 1500 ml/ha (500 ml/ha + 500 ml/ha+ 500 ml/ha at 60, 75 and 90 DAS) application in improving seed cotton yield and resulting in an extra income of Rs.29458/ha over the control.

Table 4. Effect of mepiquat chloride on monetary parameters

Treatments	Dose (ml/ha)	Cost of cultivation (Rs/ha)			Gross returns (Rs/ha)			Net returns (Rs/ha)			B : C Ratio		
		2014	2015	**Mean**	2014	2015	**Mean**	2014	2015	**Mean**	2014	2015	**Mean**
Control		38169	33416	**35793**	106016	72744	**89380**	67846	39328	**53587**	1.77	1.17	**1.5**
Mepiquat chloride 1000, Single application at 80-85 DAS		40990	35892	**38441**	120862	85176	**103019**	79872	49284	**64578**	1.94	1.37	**1.7**
Mepiquat chloride 1250, Single application at 80-85 DAS		42810	37105	**39958**	132379	92442	**112411**	89568	55337	**72453**	2.08	1.48	**1.8**
Mepiquat chloride 1500, Single application at 80-85 DAS		41338	37964	**39651**	121201	97230	**109216**	79813	59266	**69540**	1.92	1.55	**1.7**
Mepiquat chloride 1500 (3 applications @500 ml/ha + 500ml /ha + 500ml/ha at 60,75 and 90 DAS)		44606	39248	**41927**	143725	106218	**124972**	99119	66970	**83045**	2.21	1.70	**2.0**
Mepiquat chloride 1750 (3 applications @500 ml/ha + 625ml /ha+ 625ml/ha at 60, 75 and 90 DAS)		42999	35145	**39072**	131250	76272	**103761**	88251	41127	**64689**	2.04	1.16	**1.6**
De-topping at 70-80 DAS		41922	37008	**39465**	128088	87108	**107598**	86166	50100	**68133**	2.05	1.35	**1.7**
Mepiquat chloride 1500 (2 applications @750 ml/ha + 750 ml/ha at 75 and 90 DAS)		-	38804	**-**	-	103110	**-**	-	64306	**-**	-	1.65	**-**
CD (p=0.05)		2844	1719	-	19910	12036	-	17066	10316	-	NS	0.20	-

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