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DIURON INDUCED PHYTOTOXICITY IN COTTON GROWN ON RED AND BLACK SOILS

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ABSTRACT

The experiment comprised of seven treatments having varied doses of diuron 80% WP at 0.5 kg ha^{-1}, 0.75 kg ha^{1}, 1.0 kg ha^{-1} and pendimethalin 38.7% CS (677 g ha^{-1}) as preemergence (PE) application followed by postemergence application of pyrithiobac sodium10% EC (62.5 g ha^{-1}) + quizalofop ethyl 5% EC (50.0 g ha^{-1}). Non-chemical weed management treatments comprised of polyfilm, mechanical weeding (at 20, 40 and 60 days after sowing) and unweeded control. In red soil no phytotoxicity symptoms were observed in any of the herbicide treatments, but slight yellowing of seedlings was observed in diuron 1.0 kg ha^{-1} PE at 10 and 15 days after herbicide spray (DAHS) but the seedlings recovered completely at 10 DAHS. Phytotoxicity symptoms in black soils were manifested as severe yellowing of emerged cotton seedlings at 10 and 15 DAHS and the yellowing with reduced intensity persisted upto 30 and 45 DAHS in diuron 1.0 kg ha^{-1} PE treatment In the same treatment, necrosis was observed at 10 DAHS which was more pronounced at 15 DAHS and at 30 DAHS the necrotic symptoms were gradually reduced and disappeared. Seedling mortality was also observed in diuron 1.0 kg ha^{-1} in black soils which was severe at 15 DAHS, slight mortality at 30 DAHS and after 30 DAHS no mortality was observed.

INTRODUCTION

Cotton is the most important fibre crop of India, occupies prime position in the world (*Ramesh et al*., 2016). In Telangana state, cotton is the most important commercial crop, cultivated in more than 17.0 lakh ha exclusively during the kharif season. Production of cotton (*Gossypium hirsutum* L.), suffers due to many biotic constrains like weeds, insect pests and diseases etc. Weeds are responsible for losses in cotton yield to an extent of 60% (Sadangi and Barik, 2007). Presently to enhance the productivity, weeds are controlled by cultural, mechanical biological, chemical and integrated methods. Importantly, the critical period of weed competition in cotton crop is from 15 to 60 days (Prabhu *et al*., 2010) and weed management systems during this period should prevent weed interference, be economical and sustainable, reduce weed seed bank in soil, prevent weed resistance, and neither injure cotton nor reduce quantity of lint yield. Preemergence herbicides are the most important weed management interventions in weed-free establishment of the crop. So the application of preemergence herbicides provides a foundation for season long weed management.

Hargils *et al*., 2015 reported that effective method of weed control with higher economic return in Bt cotton can be achieved by sequential use of pendimethalin as preemergence followed by combination spray of quizalofop ethyl + pyrithiobac sodium with one hand hoeing at 45 DAS without any phytotoxicity to cotton. At present, pendimethalin and alachlor are the two pre-emergence (PE) herbicides registered for use in cotton besides diuron (CIBRC, 2020). As alachlor is being phased out of use by 2020, pendimethalin will be the sole available preemergence herbicide registered for use in cotton. It is a well-established fact that, using a single herbicide over long period can have adverse effects such as development of resistance in weeds and poor bio-efficacy over long-term usage. Further, continuous use of same herbicide may also negatively influence different properties of soil like soil enzyme activity and soil microbial population. Even though diuron is registered for use in cotton decades back, its usage is very low due to long residual life and phytotoxicity in the cotton as well as succeeding sensitive crops. Further, the dose registered by CIBRC is 0.75-1.50 kg ha^{-1} which is a very wide range of use. No specific recommendation is available about the rate of diuron application in soils with different textures where cotton is grown. Such recommendations are more essential for a state like Telangana where cotton grown in coarse textured red soils with low rainfall (Southern Telangana Zone) as well as in fine-textured black soils. These situations necessitate revalidation of already registered preemergence herbicide (diuron) for use in cotton in rotation with pendimethalin for effective early stage weed management. Hence, the paper deals with the assessment of phytotoxicity caused due to application of diuron in cotton cultivated in red and black soils.

MATERIALS AND METHODS

Experimental site and meteorological information: Two field experiments were carried out during Kharif 2018 at College Farm, College of Agriculture, Professor Jayashankar Telangana

State Agricultural University, Rajendranagar, Hyderabad, Telangana state. The farm is geographically located at 17º19′ N latitude and 78º23′ E longitude at an altitude of 542.6 m above mean sea level (MSL). The climate of the region is semi-arid. More than 80% of rainfall is received from South-West monsoon (June-October). Both the field trial sites are located in same experimental farm with in few hundred meter distance. Red soil experiment site was sandy clay in texture with neutral pH, non-saline and classified as Typic Haplustalf. Black soils site was classified as Vertic Haplustept with clay loam texture, slightly alkaline pH and non-saline.

Technical programme: Field experiments were laid out in a Randomized Block Design (RBD) comprising of seven treatments which were replicated thrice. "First Class BG II" cotton hybrid seeds of Bayer company were sown at a seed rate of 2.5 kg $ha^{-1.}$ Seeds were sown at a spacing of 90 x 60 cm. Thinning was done within two weeks of sowing to maintain optimum plant population. Preemergence herbicides diuron 80% WP ("Karmex" of Adama India Pvt. Ltd) at 0.5 kg ha^{-1}, 0.75 kg $ha^{-1}$and 1.0 kg ha^{-1}; and pendimethalin 38.7% CS 677 g ha^{-1} were sprayed with knapsack sprayer fitted with flat fan nozzle at two days after sowing. Spray volume applied was 500 lit ha^{-1}. Pyrithiobac sodium 10% EC 62.5 g ha^{-1} + quizalofop ethyl 5% EC 50 g ha^{-1} were sprayed at 2-3 leaf stage of the weeds. Polyfilm was spread one day before sowing and seeds were sown by making holes on film at designated spacing. Mechanical weeding was done at 20, 40, 60 DAS with power weeder (Honda F300) and an unweeded control was maintained without any weeding from sowing to harvest.

Chemical analysis of soil sample: Composite soil samples were collected randomly from each treatment and were analysed for different soil properties. Soil reaction (pH) was determined in 1:2.5 soil water suspension using pH meter (Elico LI 610) after stirring the sample with water for 30 minutes (Jackson, 1967). The electrical conductivity of the soil was determined in the supernatant of 1 : 2.5 soil water suspension that was used for pH determined by using digital EC meter (Elico CM 183) (Jackson, 1967) and expressed as (dS m^{-1}). Organic carbon content was determined in 0.5 mm sieved soil samples by wet digestion method (Walkley and Black, 1934) and expressed in percentage. Available nitrogen in the soil was determined by alkaline permanganate method as described by Subbiah and Asija (1956) and expressed as kg ha^{-1}. Available phosphorus was extracted from soil by Olsen's reagent (0.5M $NaHCO_3$) as described by Olsen *et al.* (1954). Available potassium was extracted from soil using neutral normal ammonium acetate and was determined by using Flame photometer (Elico CL 361) as described by Jackson (1967) and expressed as kg K_2O ha^{-1}.

Observations on phytotoxicity: Phytotoxicity observations were recorded in terms of yellowing, necrosis, chlorosis, seedling mortality, hyponasty and epinasty after the application of preemergence herbicides. The herbicide injury was rated using scale from 0 to 10, where 0 denotes no injury and 10 denotes complete destruction. The phytotoxicity rating observation was done at 10, 15, 30 and 45 days after herbicide spray. The visual phytotoxicity rating was adopted as suggested by Rao (2000) and is depicted in table 1.

Table 1: Visual scoring of phytotoxicity

Crop injury symptoms	Rating	Effect
No injury, normal	0	None
Slight stunting, injury or discoloration	1	Slight
Some stand loss, stunting or discoloration	2	Slight
Injury more pronounced, but not persistent	3	Slight
Moderate injury, recovery possible	4	Moderate
Injury is more persistent, recovery doubtful	5	Moderate
More severe injury, recovery is not possible	6	Moderate
Severe injury, stand loss	7	Severe
Almost destroyed, few plants surviving	8	Severe
Very few plants alive	9	Severe
Complete destruction	10	Complete

RESULTS AND DISCUSSION

Data on visual phytotoxicity symptoms like yellowing, necrosis, seedling mortality, chlorosis, epinasty and hyponasty are presented in tables 2, 3 and 4 respectively.

In red soil, necrosis, seedling mortality, chlorosis, epinasty and hyponasty were not observed in any of the herbicide treatments. Slight yellowing of seedlings was observed in diuron 1.0 kg ha^{-1} at 10 and 15 days after herbicide spray (DAHS) but the seedlings recovered completely at 30 DAHS.

In case of black soil, Chlorosis, epinasty and hyponasty were not observed in any herbicide treatments. In case of diuron 1.0 kg ha^{-1}, severe yellowing of seedlings was observed at 10 and 15 DAHS which persisted for further two to three weeks. The intensity of yellowing decreased and the fresh leaves appeared were green in colour. At 30 and 45 DAHS slight yellowing ($scale^{-1}$) was observed. Necrosis (A greyish circle with dead/ dried tissue on the top leaves) was observed at 10 DAHS ($scale^{-2}$) which became pronounced at 15 DAHS and at 30 DAHS the necrotic symptoms were gradually reduced and disappeared in diuron 1.0 kg ha^{-1}. Seedling mortality (drying and death of the emerged seedling) was also observed in

Table 2: Visual scoring of yellowing and necrosis as influenced by weed control measures in cotton

Treatments	Yellowing							Necrosis					
	Red soil			Black soil				Red soil			Black soil		
	10 DAHS	15 DAHS	30 DAHS	10 DAHS	15 DAHS	30 DAHS	45 DAHS	10 DAHS	15 DAHS	30 DAHS	10 DAHS	15 DAHS	30 DAHS
T_1	0	0	0	0	0	0	0	0	0	0	0	0	0
T_2	0	0	0	0	1	0	0	0	0	0	0	0	0
T_3	1	1	0	2	2	1	1	0	0	0	0	2	1
T_4	0	0	0	0	0	0	0	0	0	0	0	0	0
T_5	0	0	0	0	0	0	0	0	0	0	0	0	0
T_6	0	0	0	0	0	0	0	0	0	0	0	0	0
T_7	0	0	0	0	0	0	0	0	0	0	0	0	0

T1-Diuron 0.5 kg ha-1 PE followed by (fb) pyrithiobac sodium + quizalofop ethyl PoE; T2-Diuron 0.75 kg ha-1 PE fb pyrithiobac sodium + quizalofop ethyl PoE; T3-Diuron 1.0 kg ha-1 PE fb pyrithiobac sodium + quizalofop ethyl PoE; T4-Pendimethalin 38.7% CS 677 g ha-1 PE fb pyrithiobac sodium + quizalofop ethyl PoE; T5-Polyfilm (250 μm thickness); T6-Mechanical weeding with power weeder at 20, 40, 60 DAS; T7-Unweeded control

Table 3: Visual scoring of chlorosis and seedling mortality as influenced by weed control measures in cotton

Treatments	Chlorosis						Seedling mortality					
	Red soil			Black soil			Red soil			Black soil		
	10 DAHS	15 DAHS	30 DAHS	10 DAHS	15 DAHS	30 DAHS	10 DAHS	15 DAHS	30 DAHS	10 DAHS	15 DAHS	30 DAHS
T_1	0	0	0	0	0	0	0	0	0	0	0	0
T_2	0	0	0	0	0	0	0	0	0	0	0	0
T_3	0	0	0	0	0	0	0	0	0	0	2	1
T_4	0	0	0	0	0	0	0	0	0	0	0	0
T_5	0	0	0	0	0	0	0	0	0	0	0	0
T_6	0	0	0	0	0	0	0	0	0	0	0	0
T_7	0	0	0	0	0	0	0	0	0	0	0	0

T_1-Diuron 0.5 kg ha^{-1} PE followed by (fb) pyrithiobac sodium + quizalofop ethyl PoE; T_2-Diuron 0.75 kg ha^{-1} PE fb pyrithiobac sodium + quizalofop ethyl PoE; T_3-Diuron 1.0 kg ha^{-1} PE fb pyrithiobac sodium + quizalofop ethyl PoE; T_4-Pendimethalin 38.7% CS 677 g ha^{-1} PE fb pyrithiobac sodium + quizalofop ethyl PoE; T_5-Polyfilm (250 μm thickness); T_6-Mechanical weeding with power weeder at 20, 40, 60 DAS; T_7-Unweeded control

Table 4: Visual scoring of epinasty and hyponasty as influenced by weed control measures in cotton

Treatments	Epinasty						Hyponasty					
	Red soil			Black soil			Red soil			Black soil		
	10 DAHS	15 DAHS	30 DAHS	10 DAHS	15 DAHS	30 DAHS	10 DAHS	15 DAHS	30 DAHS	10 DAHS	15 DAHS	30 DAHS
T_1	0	0	0	0	0	0	0	0	0	0	0	0
T_2	0	0	0	0	0	0	0	0	0	0	0	0
T_3	0	0	0	0	0	0	0	0	0	0	0	0
T_4	0	0	0	0	0	0	0	0	0	0	0	0
T_5	0	0	0	0	0	0	0	0	0	0	0	0
T_6	0	0	0	0	0	0	0	0	0	0	0	0
T_7	0	0	0	0	0	0	0	0	0	0	0	0

T_1-Diuron 0.5 kg ha^{-1} PE followed by (fb) pyrithiobac sodium + quizalofop ethyl PoE; T_2-Diuron 0.75 kg ha^{-1} PE fb pyrithiobac sodium + quizalofop ethyl PoE; T_3-Diuron 1.0 kg ha^{-1} PE fb pyrithiobac sodium + quizalofop ethyl PoE; T_4-Pendimethalin 38.7% CS 677 g ha^{-1} PE fb pyrithiobac sodium + quizalofop ethyl PoE; T_5-Polyfilm (250 μm thickness); T_6-Mechanical weeding with power weeder at 20, 40, 60 DAS; T_7-Unweeded control

diuron 1.0 kg ha^{-1} which was severe at 15 DAHS, slight mortality at 30 DAHS and after 30 DAHS no mortality was observed.

Yellowing of cotton leaves persisted upto 15 DAHS (scale 1) in reds soils, whereas in black soils the yellowing was observed upto 45 DAHS. In red soils cotton leaves did not develop necrotic spots in any of the diuron treatments. Severe necrosis (upto 20 % Plants) was observed at 15 DAHS in 1.0 kg ha^{-1} diuron application in black soils and severity reduced with the increase in age of the crop and necrotic spots were observed in 10 % plants at 30 DAS. No seedling mortality caused by diuron phytotoxicity was observed in red soils. Where as in black soils, seedling mortality persisted up to 30 DAHS, which resulted in depleted population at harvest stage in diuron 1.0 kg ha^{-1} treatment.

General recommendation of pre-emergence herbicides to various crops grown in soils with different textures always advocate application of higher rates of herbicides when the soils are finer in texture (higher clay content) and lower doses when the texture is medium to coarse (lower clay content). However, in the present experiment, among the three diuron treatments, more severe phytotoxicity was observed in black soils than in red soils at the same rate of herbicide application. Most severe phytotoxicity was observed in black soils in 1.0 kg diuron application.

This kind of anomalous phytotoxicity caused by diuron can explained in two different ways. The experiment was conducted in red and black soils having clay content, CEC and pH values of 21.4 %, 19.54 c mol (P+) kg^{-1} soil and 7.32 respectively in red soil and 38.0 %, 33.26 c mol (P+) kg^{-1}soil and 8.45 respectively in case black soil. The organic carbon content was slightly higher in black soils (0.53 %) compared to the red soils (0.45%). Analysis of the physico-chemical data indicate that the black soil was having higher clay content, CEC and slightly more organic carbon than red soils and should naturally have more adsorption capacity for diuron. However, the black soil was moderately alkaline with higher pH compared to red soil which was neutral.

Even though sorption of diuron is dependent of the clay content, and CEC, at moderately alkaline range of soil reaction, pH becomes the deciding factor influencing the adsorption of diuron onto the clay complexes. At high pH value, diuron becomes an anion and the repulsion forces between clay surfaces and diuron reduce the adsorption. At low pH value, diuron may become a proton and higher adsorbed amount may be observed. Eventhough the organic carbon plays significant role diuron sorption, in the present experiment, the difference in organic carbon content between two soils was very less (less than 0.1 %). Hence, the alkaline soil reaction of the black soil might have resulted in lower adsorption of diuron making the herbicide more available to be taken up by the growing cotton roots, resulting in higher phytotoxicity.

The adsorption of phenyl urea herbicides to soil particles is rather low but depends on soil characteristics and pesticide physicochemical properties. Adsorption of phenylurea herbicides can however also be affected by soil characteristics other than organic matter content or composition. Soil pH appears to play an important role. Indeed, pH was reported to be the second most important factor after organic matter content for influencing the adsorption of phenylureas to soil (Coquet and Barriuso, 2002). Relatively higher adsorption is recorded in acidic soil than in basic soil (Ertli *et al*., 2004). The partition coefficient of phenyl urea herbicides depends strongly on the organic carbon content of the soil (Coquet and Barriuso, 2002).

A correlation was also found between adsorption of diuron and content of magnesium and soil texture Liu *et al.* (1970). El-Nahhal *et al.*, 2013 stated that soil organic matter and pH affect the adsorption of diuron. The low adsorption of diuron in a soil is probably due to high pH (8.0). Under this condition, the organic fraction in soil is the main adsorbent. This statement is strongly supported by El- Nahhal and Safi (2005) and Liu *et al.* (2010) who found that the adsorption of diuron on the selected soils were rather high at low pH values and decreased with the in-creasing pH values of the suspension.

The adsorption–desorption behaviours of diuron were investigated in six cultivated soils of China. The effect of system pH and temperature were also studied. The data fitted the Freundlich equation very well. The extent of diuron adsorption on soil was at rather high level under low pH value conditions and decreased with increasing pH value (Liu *et al.*, 2010).

The second explanation for more severe phytotoxicity in black soils is that, due to faster movement of diuron in red soils beyond the root zone compared to black soils. The black soils by virtue of having higher clay content (38.0 %) and lower transmission-porosity might have resulted in lower leaching of diuron than in the red soils (which was coarser texture with lesser clay content of 21.4%). Rainfall (19.4 mm on 13th july [day of sowing], 5.2 mm on 14th July, 3.4 mm on 15th July[day of herbicide spray], 2.2 mm on 16th July, 1.8 mm on 17th July and 2.0 mm on 18th july followed by dry period of more than one week) received in immediate two weeks after herbicide application showed that, the rainwater was not sufficient to leach down the diuron below the root zone in black soil which might have resulted retention of diuron in the pore-water with in the root zone in black soils which resulted more severe phytotoxicity in black soils compared red soils. When a pesticide is applied to the soil surface, the initial concentration at the topsoil immediately begins to diminish due to microbial and chemical (including photochemical) degradation and to volatilization. Rainfall causes further dissipation from the soil surface through both runoff and leaching processes (Southwick *et al.*, 2003). The phenylurea herbicides generally have relatively high water solubility and low tendencies to sorb to soil, rendering them mobile in soil. (Sorensen *et al.*, 2003). Field experiment by Gooddy *et al.* (2002) also indicate that, high concentrations of diuron and some of its known metabolites in the plough layer of a soil following normal field treatment in a monitoring programme lasting for 50 days. Diuron was detected in porewater in concentrations greater than 1 μg L-1 in 97% of the measurements made. Three metabolites known from initial degradation of diuron were also detected in soil and pore-water with concentrations exceeding 1 μg L-1throughout the entire monitoring period.

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