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Lethal soil temperature under plastic mulch on growth and suppression of nutgrass

R. Devendra*, S.B. Manjunatha, N. Naveen Kumar and T.V. Ramachandra Prasad
Department of Agronomy. University of Agricultural Sciences, Bengaluru, Karnataka 560 065

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ABSTRACT

Lethal soil temperature impedes tuber formation, enhances respiration and depletes the tuber's reserves and reduced size and viability. Attempts were made to increase soil temperature to lethal level by clear plastic mulch (PM), with hot water irrigation (HW), and its effect was assessed on growth of *C. rotundus*. During June 2010, quantity and frequency of hot water irrigation required to maximize the soil temperature was standardized using rain out shelter, load cell–digital weighing device by gravimetric method (40 liter/m^2 and once in 4 days). During September 2011, effect of randomly stitched varied thickness 50, 75, 125 and 175 micron plastic mulch of size 1.25 x 1.25 m^2 was spread over *C. rotundus* infected micro-plot and HW irrigated on soil temperature was assessed. Increased soil temperature under different thickness PM was at par with 175 micron. Further, the mean soil temperature and day/night fluctuation in plastic mulch with hot water (PM + HW) plot was congenial for *C. rotundus* growth, enhanced spouting and development of new tubers during September. During April 2012, hot water irrigated during 2.00-3.00 PM, soil temperature reached lethal level. Further, woolen blanket cover (WBC) between 4.0 PM to next day 9.0AM, retained warm temperature during night and maintained higher initial soil temperature next day. Thus during April, led soil temperature (58° C) to lethal level during 30 days of integrating PM + HW + WBC and caused drastically reduction of biomass (87%), number of tubers (62%) per 0.025m^2 with loss of tuber viability.

Key words: *Cyperus rotundus*, Hot water, Lethal soil temperature, Nutgrass, Plastic mulch

Solar radiation penetrates transparent plastic mulch; water vapors present lower side reflects the long wave radiation emitted by soil thus soil become warmer and creates green house effect (Shekh and Patel 2006). Plastic mulch over plant canopy between 4.0 PM to next day 10.00AM increased relative humidity (RH), and air temperature above ambient by 10.7% and 1^{0}C during February 2011 and 2.1% and 2.5° C during May 2010 apart from elevated CO_2 led to enhanced growth of weed and altered herbicide efficacy along (Mahesha 2011). Plastic mulch enclosure increased CO_2 during night, which was utilized during early morning hours (6-10 AM) led to increased photosynthates. Thus assimilated 15, 97 and 84% more carbon at CO_2 700 ppm than ambient CO_2 by exposing to 30/20, 30/25 and $35/25^{0}$C day/night air temperature in pine apple respectively, (Zhu *et al*. 1999) and in cucumber (Taub *et al*. 2000). Thus growth and development of weed depends on soil temperature, air temperature and CO_2 level.

Soil temperature determines size, shape, quality of root and hastens uptake and translocation of water, nutrient (Dong *et al.* 2001). Lethal soil temperature harmful to root activity, causes lesion of stem, stops tuber formation of potato (above 29° C) and rate of decomposition increased. Lethal air temperature injuries like 1) thermal death point (50° C), 2) reduced uptake and assimilate (Ca uptake at 28° C in maize), 3) nitrate reductase activity decreased, 4) reduce shoot and root growth, 5) pollen abortion and 6) dehydration and scorching of leaves and stem were noticed.

Water saturated soil helps to conduct heat to deeper layer of soil. Well prepared seed bed (free from sharp debris), irrigated before plastic mulching killed- i) root knot nematodes, ii) noxious weeds seed, ii) root rot pathogens and improves nutrients thus led to healthier plants by solarization. Mean and day/night soil temperature fluctuation optimized the growth. For instances, four degree celsius day/night temperature fluctuation had 96% sprouting of tuber. Higher diurnal fluctuation of 0, 4, 8 and 12^{0}C with same mean 32° C, *viz*. 32/32, 30/34, 28/36 and 26/38 caused 72, 75, 87 and 97% sprouting of purple nut sedge tubers (Travior *et al*. 2008). Tuber viability had 50% thermal time (TT_{50}) of 71, 23, 1.8 and 0.5 hrs for 45, 50, 55 and 60° C respectively. Thus twenty three hours of exposure at 50^{0}C had same effect as that of 30 min at 60° C on loss of tubers viability

***Corresponding author:** dev.cuti@gmail.com

(Webster 2003). Emerging shoot of purple nut sedge has sharp tip and tear the plastic mulch. Hence attempts were made to maximize soil temperature to lethal level (60° C) by hot water irrigation (HW), below polythene mulch (PM) and by covering, woolen blanket cover (WBC) between 4 AM - 9 AM, during different seasons to assess their efficacy on soil temperature at different depth and suppression of purple net sedge sprouting.

MATERIAL AND METHODS

Assessment of quantity of hot water per pot

During June 2010, pots filled with red loamy soil were maintained at different soil moisture *viz.* 60, 80 and 100 field capacity (FC). These pots were surface irrigated with hot water (HW) after covering with plastic mulch (PM) of 175 micron thickness to quantify hot water required to raise the soil temperature to lethal level. Soil moisture of 60, 80 and100 FC maintained by irrigating Q60, Q80 and Q100 quantity (ml/ pot) using the following equation 1.

$$Q100 = W100 — Wpds \quad —(1)$$

Where, W100 (g) indicates weight of pot at 100% FC which includes pot wt. + dry wt. of soil + 100% FC soil moisture (12 h after irrigating the pot till the water flow out of drainage), Wpds denotes pot wt with dry soil (g) and Q100 is the quantity of water (g = ml) per pot at 100 FC. Q100 value for each pot was obtained and multiplied with 0.6 or 0.8 to get Q60 and Q80 quantity of hot water required to reach 60 and 80 % FC respectively. Care was taken to keep pots under rain out shelter (ROS), irrigated with varied quantity of water to maintain different FC by using standardized gravimetric method with load cell and digital weighing device as described by Udaya Kumar *et al.* (1998).

Soil temperature was recorded using digital thermometer having -50 to 300° C range after hot water irrigation at different depth 5,10 and 15 cm at 10 min interval for 90 min. Soil moisture reached 60% FC every 4th day for sandy loam type and surface irrigated with HW recorded maximized soil temperature. Fourty L/m^2 of hot water (20 + 20 L/m^2 at 30 min interval) once in four days was required to maximize the soil temperature. Mean soil temperature at different depth with PM, PM + HW, HW and control was computed with deviation for different days of irrigation having varied hot water temperature 65-85° C. Pattern of soil temperature rise in different depth, time taken to reach and duration of maximum soil temperature retained was assessed.

Assessment of different depth soil temperature and its effect on *C. rotundus* under field condition

During May 2011, *C. rotundus* infested field was demarked by 2 x 2 m^2 plots with solar water heater of 200 litres capacity irrigating to center of the demarked plot. Spade width of soil was removed from a depth of 15 cm around the plot’s periphery and PM was made air tight by tucking the edges of the mulch with removed soil around the periphery. Below PM was irrigated with hot or normal water (160 L/4 m^2) and soil temperature was recorded at 5, 10 and 15 cm depths. Digital thermometer was placed in different concentric circles having varied distances and soil temperature was recorded after normal/hot water irrigation at 10 min interval for 90 min form three concentric circles in each replication. Replications consistsed of different days of irrigation (as quantity of hot water was 160 lit/4 m^2) which led to variation in hot water temperature (65-85°C). Thus mean soil temperature maximized was altered in PM+HW and HW treatments between replications and in different depths. However, pattern and duration of maximized and retention time showed similar pattern of pot culture hence data was not presented.

During September 2011, different thickness of PM (50, 75, 125 and 175 micron) sheets of size 1.25 x 1.25 m^2 was stitched together by placing randomly and it was spread over weed canopy of 2 x 2 m^2 plot. Four thicknesses of PM in plots with or without hot/ normal water surface irrigation in main plots and control in three replications was laid out in split plot design. The soil temperature was recorded at 30, 60 and 90 min. The data revealed that variation in soil temperature was not significant between thicknesses of PM after hot water irrigation (HW). Therefore, during other seasons, only PM of 175 micron was used. HW was surface irrigated at 10-11 AM during May 2011, September 2011 and March 2012 at 1-2 PM of April 2012. Five replications with four treatments (control, HW, PM + HW, PM + HW + WBC) were maintained during other seasons.

Mean soil temperature was computed over different depths, at three different distance of concentric circles, 4 replicates and different interval after irrigation at varied irrigation days. Biomass (fresh weight g/0.025 m^2) using top loading digital display SAMSUI (2 kg) balance and number of tubers of different sizes (#/0.025 m^2) distributed at various depth from 15 cm was recorded by harvesting the plant material after 30 days of treatments. Viability of tubers was assessed using standard tetrazolium chloride test by slicing the tuber and exposing the cut end to the tetrazolium chloride solution in Petri dish with filter paper. Intensity of pink colour was used to count viable tubers.

RESULTS AND DISCUSSION

Plastic mulch with hot water irrigation (PM + HW) had higher soil temperature than control for all the depths (Fig. 1). Shallow depth at 5 cm reached maximum temperature of 57° C by 20 min after hot water irrigation whereas 10 and 15 cm depth reached maximum temperature of 48 and 43° C by 30 and 40 min, respectively. The highest soil temperature was maintained for 90 min for all depths during June 2010. April month solarization with 50 micron PM raised the soil temperature to 51.3 and 48.4 from control 41.8 and 39.5 for 5 and 10 cm depth (Nanjappa *et al*. 1999). Standard error for each mean soil temperature denotes variation in hot water temperature between days of irrigation. Low temperature of 36.4° C during September 2011 and highest of 54.6 (lethal soil temperature) during April 2012 with PM + HW with woolen blanket cover during night time (WBC) was recorded (Table 1). During May 2011, September 2011, March and April 2012 temperature increase was 10.8, 4.8, 11.4 and 9.1° C in HW plot than control. Whereas, with PM+HW soil temperature was of 5° C higher than HW irrigation at all seasons. Further, with PM + HW + WBC 2° C more lethal soil temperature was reached during April 2012. Thus importance of hot water irrigation to raise the soil temperature to lethal level was emphasized. According to Department of Agrometeorology, Bengaluru has maximum soil and air temperatures during April; Puna and Kolkata during May and New Delhi during June months. Thus, April month for Bengaluru well suited to impose PM or PM + HW treatment to increase soil temperature to lethal level.

Table 1. Effect of plastic mulch, hot water irrigation and their combination on different seasons soil temperature fort Bangalore conditions (Mean of 3 or 4 irrigations and different depths)

Treated plot	May 2011	September 2011	March 2012	April 2012**
Hot water (HW)	39.1[b]	31.7[a]	41.2[b]	48.0[b]
Plastic mulch(PM) + HW	44.1[a]	36.4[a]	46.5[a]	52.9[a]
PM + HW + WBC	NA	NA	NA	54.6[a]
Control	29.9[c]	29.9[b]	29.8[c]	38.9[b]
LSD (P = 0.05)	2.21	2.87	4.12	6.14

** indicates soil temperature measured during 2.00PM during April 2012, rest of soil temperature was measured during 10 AM; plot with PM + HW + WBC treatment was introduced later thus data was not available (NA); WBC denotes woolen blanket cover during night time to retain high soil temperature and initial soil temperature next day.

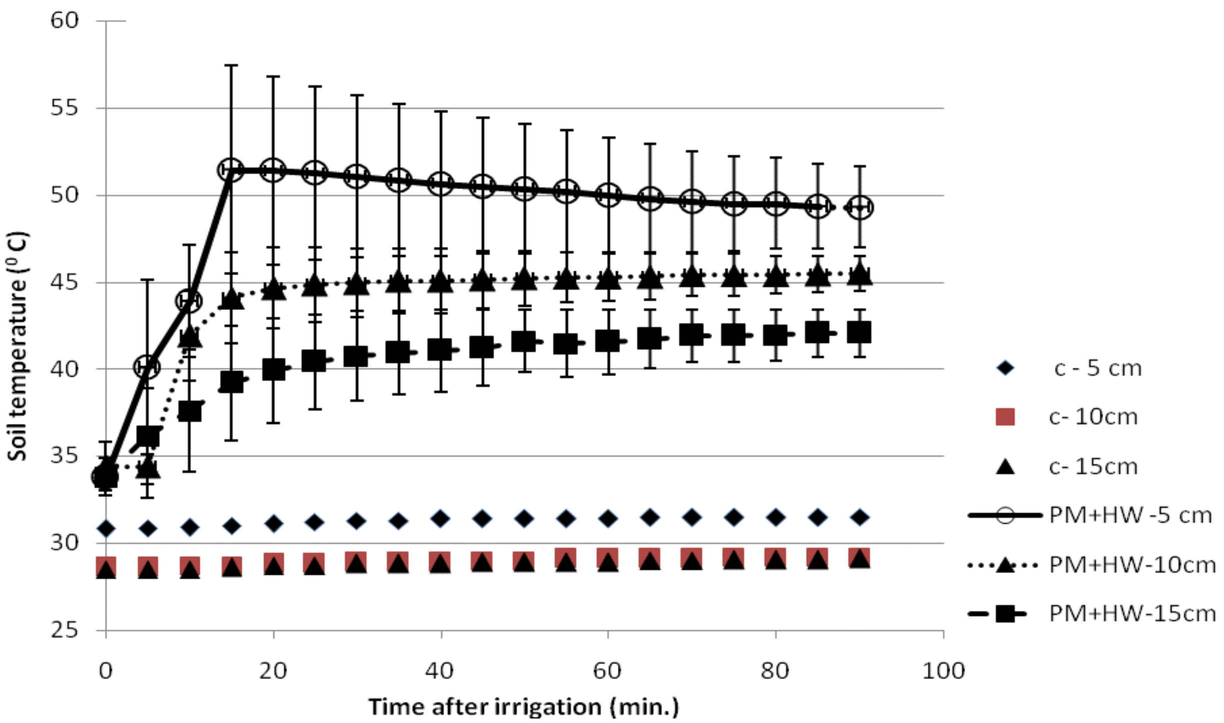

Fig.1. Effect of PM + HW on pattern of soil temperature reaching maximum and retention time of periodic mean and its deviation (due to replications, different irrigation days, different concentric circles) during June 2010 under field condition.

Table 2. Effect of different seasons' soil temperature on biomass (g/ 0.025 m²) and number of tubers/ 0.025 m² of *Cyperus rotundus* after 30 days of plastic mulch

Treatment	No. of tubers/0.025 m²				Biomass (g/0.025 m²)			
	May-11	Sep.-11	March -12	April -12	May-11	Sep.-11	March -12	April -12
Control	144.5[a]	31.6 (5.79[c])	69[a]	69.5[a]	363.1[a]	115(10.7[c])	73[a]	141[a]
HW	81.4[b]	57.2(7.69[b])	73[a]	41.0[b]	196[b]	196(14.0[b])	61[b]	84.0[b]
PM + HW	53.6[b]	97.2(9.96[a])	28[b]	30.5[c]	127[b]	331(18.2[a])	25[c]	68[c]
PM + HW + WBC	NA	NA	NA	26.0[c]	NA	NA	NA	18.2[d]
LSD (P=0.05)	50.7	(1.57)	15	7.44	94.8	(3.5)	10.1	10.7

Different alphabet denoted and superscripts showed significant from each other # figures parentheses are origin valves and subjected to square root transformation

Further a strong relation between temperature of hot water used for irrigation and maximum soil temperature was noticed. Correlation coefficient values (r= 0.744* and 0.667* for 5 and10 cm depth, respectively) across seasons (Naveen Kumar 2012) and between soil temperature of HW and PM + HW (r= 0.947**, 0.972** and 0.962** at 5, 10 and 15 cm depth, respectively) (Anonymous 2011). Thus prediction of soil temperature for different depth in PM + HW was possible using soil temperature of HW treatment.

Highest biomass (331 g/0.025 m²) was recorded during September 2011 with PM + HW and least biomass (18 g/0.025 m²) during April 2012 with PM + HW + WBC (Table 2). Further, during April 2012 the soil temperature was 9.1°C, 14°C and 15.7°C higher than ambient due to HW, PM + HW and PM + HW + WBC, respectively. This led to decrease in total biomass of 40, 52 and 87 and tubers population by 41, 56 and 62 per cent than control in HW, PM + HW and PM + HW + WBC, respectively. A strong positive relationship between number of tubers and biomass of *C. rotundus* grown at different seasons with varied soil temperature was observed (r = 0.849**). But, soil temperature has showed significant negative relationship with biomass (r = -0.586*) and tuber number (r = -0.583*) suggesting that increase in soil temperature to lethal level reduced biomass and number of tubers. The PM + HW maintained high soil temperature at all depths and consequently showed significantly lower biomass and tuber number than control after 30 days during summer months, but PM + HW during September 2011 had higher sprouting and maximum growth. Minimum, maximum and optimum temperature for *C. rotundus* bud dormancy was 10, 45 and 30-35° C (Holt and Orcutt 1996). During September, the mean soil temperature for PM + HW was raised 32.5 from 24 and 41.5 from 35° C of control for 1st and 2nd irrigation, respectively. Similarly, day/night temperature were 38.6/20, 43/22 for PM + HW than 28/20, 34/22 for control for 1st and 2nd irrigation thus diurnal soil temperature fluctuation (ÄT) was 18.6, 21.3 for PM + HW than 8, 13.4 for control, respectively, thus optimized the (ÄT) soil temperature. Maximum purple nutsedge shoot elongation occurred at 40/30° C for 1/23 h or 30/20° C for 15/9 h it was the bud response to alternating temperature (Sun and Nishimato 1999). Four degree celsius diurnal temperature day/night fluctuation 38/34 had 75% sprouting of tuber. Higher diurnal fluctuation of 12° C with same mean 32° C *viz.* 38/26 caused 97% sprouting of purple nut sedge tubers (Travior *et al.* 2008). GA_1 level was regulated by temperature fluctuation (30 min exposure to 35° C from 20° C) in presence of light which led to bud breaking and shoot elongation in pea (Stavang *et al.* 2007). Thus temperature fluctuation during September with prevailing optimum mean temperature might have helped the sprouting of tuber and elongation of shoot by elevated growth regulator.

The emergence of purple nutsedge occurred from 95% of tubers present in upper 15 cm soil layer. (Travior *et al.* 2008). In PM + HW, tubers experienced lethal soil temperature which led to lower root activity and shoot experienced green house effect, *viz.* high RH, air temperature, elevated CO_2 (Mahesh 2011), ethylene (Naveen Kumar 2012) which led to senescence of shoot. Thus impeded tuber formation and enhanced respiration depleted the tuber's reserves reduced tuber size and viability. Plastic mulch with hot water irrigation effectively reduced tuber population, size and viability of small, medium and large *C. rotundus* till 15 cm depth than control. Development of technology to heat the soil till deeper layer and get other benefits of solarization is the need of the hour.

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