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Effect of maize based intercropping system on purple Nutsedge (*Cyperus rotundus* L.) control

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Abstract
The *Cyprus rotandus* is a perennial menace weed which cause potential yield loss in crop plants. The present study was conducted to reveal the effect of maize allelochemicals and maize based cropping system for efficient and ecofriendly management. The study was designed to evaluate in randomized block design with three replications during *summer, 2021* at Agricultural College and Research Institute, Madurai. A total of nine treatments were formulated for evaluation of *Cyperus rotundus* growth and development. The parameters *i.e*., height, density, dry weight, and nutrient uptake of *Cyperus rotundus* were recorded at 20, 40, and 60 days after sowing. Amongst the treatments T_8- Application of glyphosate at 1.5-2.0 kg ha^{-1} in maize identified as best suited treatment to control the *Cyper rotandus* in terms of weed control efficiency they obtained at 20 DAS (62 per cent), 40 DAS (95 per cent), and 60 DAS (91 per cent). The treatments T_1-maize as a sole crop and T_2- cowpea with maize intercropping obtained with weed control efficiency of 73.63 and 71.08 percent, respectively at 60 DAS. Being the application of glyphosate at 1.5 to 2.0 kg ha^{-1} in maize field (T_8) said to be the best treatment, by adopting the environmentally safe approaches the treatments cowpea with maize at 4:1 ratio (T_2) and maize as a sole crop (T_1) are recommended for eco-friendly management of *Cyperus rotandus*.

Keywords: *Cyperus rotundus*, eco-friendly, glyphosate, intercropping system, weed control efficiency

Introduction
Purple nutsedge (*Cyperus rotundus* L.) is one of the most significant weed problems in many region of the world (Shabana *et al*., 2010) [22]. It has been found in 52 different crops in 92 different countries. Shores, wet meadows, ditches, turf, ornamental areas, agricultural fields, moist road sides, sandy soils, river bottoms and waste lands are all common habitats for *Cyperus rotundus* to thrive. (Holm *et al*., 1977) [9]. In India, it is primarily found in cotton, rice, sugarcane, and maize crops cultivated in the Indus valley throughout the summer. (Iqbal and Cheema, 2008) [10]. *Cyperus rotundus* is a tropical, subtropical, and temperate zone weed that is perennial, tenacious, and prolific. The plant grows to a height of 20-60 cm with thin leaves that are shorter than the stem. The rhizomes are white and mushy in the early stages of development, with crusty leaves, and subsequently become fibrous, woody, and dark brown, with numerous long-creeping stolon. (Sivapalan and Jayadevan, 2012) [25]. It is a troublesome C_4 weed, characterized by high photosynthetic efficiency, compared to C_3 weeds (Lati *et al*., 2011) [14]. It's a weed with high competition, especially when there's a high level of nitrogen in the soil. (Santos *et al.*, 1998) [20]. Purple nutsedge competitive advantage may be shifted to crops through cultural techniques such as smother cropping. Purple nutsedge lack of aggression in crops that quickly develop a shadow canopy to take advantage of nutsedges' shade sensitivity. Thakur *et al.* (I989) [26] reported similar control of nutsedge by cover cropping and raising intercrops. To be effective, herbicide must be translocated throughout the rhizome and tuber network of the plant. Glyphosate has been found to be more effective in controlling purple nutsedge due to its rapid translocation to the tubers (Bhatia *et al*., 2001) [5]. However, the failure of herbicides to control or desiccate dormant tubers meant that they could not entirely eliminate the plant. Chemical weed control may also pose a greater risk to human and environmental health (Duke *et al*., 2001) [6]. Increased reliance on synthetic herbicides in many agricultural systems has resulted in adverse impacts such as weed shifts, weed resistance, and non-target toxicity (Zhang, 2003) [28], necessitating research into ecologically safe and cost-effective weed management options. Maize is one of the pivotal food grain crop in the world next to rice and wheat. The crop is considered as "queen of cereals" and "miracle crop" due to its versatile nature and high yielding ability among cereals.

There have been several research on maize's Allelopathy influence on weed suppression. Growing maize as one of the cultivars in a cropping system integrating allelopathic maize with non allelopathic crops by intercropping can be studied to manage one of the world's worst weeds, *Cyperus rotundus* (Jabran k, 2017) [11]. Kato-Noguchi *et al*. (2000) [12] reported that allelochemicals were produced in the young maize seedlings. These allelochemicals reduced the enzyme activities, root growth and germination in seeds of other plant species including weeds (Kato-Noguchi, 2008) [13]. The present study was, therefore, carried out to study the maize root exudates and maize based intercropping system to control the *Cyperus rotundus* growth and development.

Materials and Methods

The field experiment was conducted during summer 2021 (May-July) at Agricultural College and Research Institute, Madurai, Tamilnadu. The experimental farm is situated at 9°97'N latitude and 78°20'E longitude with an elevation of about 147 m above Mean Sea Level. The track is located in the southern agro-climatic zone of Tamil Nadu. The soil type of experimental field was sandy clay loam, which represents the 'Madukur' series and also it's taxonomically classified as *Typic haplustaf* having pH 7.32, bulk density 1.35 Mg m^{-3}, low organic carbon content (0.46). Soil samples for 0–15 cm depth at the site were collected and tested prior to applying treatments and the basic properties were low available nitrogen (267.2 kg ha^{-1}), available phosphorus (17.1 kg ha^{-1}), available potassium high (298 kg ha^{-1}) and alkali in reaction. The gross and net plot size were 5.3 x 4.3 m^2 and 5.0 x 4.0 m^2, respectively. In order to find out the best *Cyperus rotundus* control treatment in different maize based intercropping system, field investigation was carried out with different cropping system like cowpea with maize, sorghum with maize, pearl millet with maize, these are all sown sole and intercrop. The experiment was laid out in randomized block design and replicated thrice. The following treatments were used in the experiment which includes T_1- Maize as Sole crop, T_2- Cowpea + Maize at (4:1 ratio), T_3- Cowpea as Sole crop, T_4- Sorghum + Maize at (4:1 ratio), T_5- Sorghum as Sole crop, T_6- Pearl millet + Maize at (4:1 ratio), T_7- Pearl millet as Sole crop, T_8- Application of herbicide glyphosate @ 1.5-2.0 kg/ha in the maize field and T_9- Control (open field without crop and treatment). After sowing, the first irrigation was applied and third day life irrigation was given. The timing of subsequent irrigations was determined based on the soil and rainfall characteristics. The recommended fertilizer rates for maize were 135:62.5:50 NPK kg ha^{-1}, sorghum 90:45:50 NPK kg ha^{-1}, pearl millet 70:35:35 NPK kg ha^{-1}, and cowpea 25:50:25 NPK kg ha^{-1}. The existing weed management technique in maize was glyphosate application at 1.5-2.0 kg ha^{-1} for comparison to various treatments of maize based intercropping system as limiting variables in impediment of *Cyperus rotundus* through competitive features such as nutrients, allelochemicals and shadow impact. Each treatments plot *Cyperus rotundus* was tagged and observations were made on its density (numbers m^{-2}), height of *Cyperus rotundus* (cm), nutrient uptake of *Cyperus rotundus* (kg ha^{-1}) and *Cyperus rotundus* dry weight (g m^{-2}). *Cyperus rotundus* population and dry weights were converted using square root x+0.5, and the transformed data were utilised for statistical analysis. Weed control efficiency on *Cyperus rotundus* was calculated as per the procedures given by Mani *et al*. (1973) [16] and expressed in percentage.

$$WCE = \frac{Wdc - Wdt}{Wdc} X\ 100$$

Where

Wdc - Weed densityin control plot,
Wdt - Weed density in treatment plot

Result and Discussion

Effect of maize based intercropping system on *Cyperus rotundus* height (cm)

The different maize based intercropping system influence the weed height of *Cyperus rotundus* significantly. Among the different maize based intercropping system, application of glyphosate at 1.5-2.0 kg ha^{-1} in maize field was recorded lower weed height of 23.68, 6.32 and 11.31 cm on 20, 40 and 60 DAS (Table 1). It was at par with maize as a sole crop on 20 DAS. In 20 DAS the *Cyperus rotundus* height reduced by crop competition and allelopathy effect of maize. *Cyperus rotundus* is more susceptible to shade, therefore optimum planting densities of maize as an intercrop may be sufficient to minimize the weed's prevalence (Olorunmaiye *et al*., 2013) [18]. Natural substances (allelochemicals) are produced in maize (*Zea mays* L.), according to Jabran.k, (2017) [11], which assist the plants develop competitive against weed and other crop. In 40 and 60 DAS the *Cyperus rotundus* height reduced by application of glyphosate. Glyphosate is a broad spectrum of systemic herbicide and also it is non-selective nature. It is prevents the biosynthesis of aromatic amino acids, amino acids are the building block of protein. Once protein production stopped, the growth of *Cyperus rotundus* also stopped. (Amoakwah *et al*., 2020) [3]

Table 1: Effect of maize based intercropping system on *Cyperus rotundus* height (cm)

Treatments	20 DAS (cm)	40 DAS (cm)	60 DAS (cm)
T_1-Maize as Sole crop	24.18	32.83	35.63
T_2-Cowpea + Maize at (4:1) ratio	28.71	33.29	36.36
T_3-Cowpea as Sole crop	37.52	44.98	47.11
T_4-Sorghum + Maize at (4:1) ratio	29.33	34.43	37.98
T_5-Sorghum as Sole crop	32.92	38.34	42.31
T_6-Pearl millet + Maize at (4:1) ratio	36.97	43.13	46.78
T_7-Pearl millet as Sole crop	42.85	49.56	52.49
T_8-Application of herbicide glyphosate @ 1.5-2.0 kg/ha in maize field	23.68	6.32	11.31
T_9-Control (open field without crop and treatment)	46.57	54.47	58.81
S.Ed	1.40	1.62	1.74
CD (p=0.05)	2.97	3.45	3.70

DAS - Days after sowing

Effect of maize based intercropping system on *Cyperus rotundus* density (numbers m^{-2})

Intercropping system and weed control practices markedly influenced by density of *Cyperus rotundus* at all the stages of crop growth. The density of *Cyperus rotundus* significantly lower under application of glyphosate at 1.5 to 2.0 kg ha^{-1} in maize field (123.33 numbers m^{-2}) at 20 DAS (Table 2). It was on par with maize as a sole crop. In 20 DAS the reduction in density of *Cyperus rotundus* significantly attributed to C_4 pathway of maize and competition stress created by the canopy of more crops per unit area having suppressive effect on associated weeds, thus preventing the weeds to attain full growth and development (Ali *et al*., 2017) [1]. At 40 and 60 DAS application of glyphosate at 1.5 to 2.0 kg ha^{-1} was recorded lower density 11.33 and 20.67 numbers m^{-2} compare to other treatments. This is followed by maize as a sole and cowpea with maize at 4:1 ratio. Glyphosate used for post-emergence herbicide. Glyphosate has considerably on purple nutsedge and has effectively reduced the population in maize based cropping system (Webster *et al*., 2008) [27].Sprayed at 1.5 to 2.0 kg ha^{-1}, glyphosate consistently reduced *Cyperus rotundus* growth and density by more than 80% while having no effect on maize production. Glyphosate herbicide spray was successfully controlling the *Cyperus rotundus* density. (Reddy and Bryson, 2009) [19]

Table 2: Effect of maize based intercropping system on *Cyperus rotundus* density (no. m^{-2})

Treatments	20 DAS (no.m^2)	40 DAS (no.m^2)	60 DAS (no.m^2)
T_1-Maize as Sole crop	124.67 (11.21)	92.03 (9.64)	65.67 (8.16)
T_2-Cowpea + Maize at (4:1) ratio	156.15 (12.53)	101.66 (10.13)	72.82 (8.59)
T_3-Cowpea as Sole crop	238.01 (15.45)	178.33 (13.38)	144.33 (12.05)
T_4-Sorghum + Maize at (4:1) ratio	159.33 (12.66)	107.33 (10.41)	76.67 (8.81)
T_5-Sorghum as Sole crop	193.21 (13.94)	134.33 (11.63)	101.21 (10.11)
T_6-Pearl millet + Maize at (4:1) ratio	231.05 (15.23)	172.02 (13.15)	138.19 (11.80)
T_7-Pearl millet as Sole crop	281.67 (16.81)	238.67 (15.48)	198.67 (14.13)
T_8-Application of herbicide glyphosate @ 1.5-2.0 kg/ha in maize field	123.33 (11.15)	11.33 (3.51)	20.66 (4.65)
T_9-Control (open field without crop and treatment)	328.66 (18.16)	294.04 (17.18)	297.02 (17.26)
S.Ed	0.59	0.49	0.43
CD (p=0.05)	1.26	1.04	0.92

DAS - Days after sowing, Data in parentheses are $\sqrt{x}$+0.5 transformed value

Effect of maize based intercropping system on *Cyperus rotundus* dry weight (g m^{-2})

The maize based intercropping system exerted significantly influence on reducing the dry weight of *Cyperus rotundus* at 20, 40 and 60 DAS. At 20 days after sowing the application of glyphosate @ 1.5 to 2.0 kg ha^{-1} (81.31 g m^{-2}) and maize as a sole crop (84.19 g m^{-2}) was recorded lower dry weight (Table 3). It both was statistically similar results treatments. Photosynthetically active radiation below maize canopies decreased with increasing maize population and corresponded to reductions in purple nutsedge above - ground biomass, tuber weight and tuber number. These results demonstrate that available light is a major factor in purple nutsedge competition with maize. The dry weight of purple nutsedge was reduced at high maize densities. This result supported with Milan *et al*. (2018) [17] and Ghafer *et al*. (1983) [8]. At 40 and 60 DAS application of glyphosate at 1.5 to 2.0 kg ha -1 was greatly reduced the dry weight of *Cyperus rotundus* (9.33 and 13.63 g m^{-2}), respectively. Glyphosate can be applied during the growing season directly over the crop for non-selective weed control with limited injury to the crop. This offers greater potential for a total post-emergence system. Glyphosate is effective on *Cyperus rotundus* (Ameena and George, 2004; Shaw *et al*., 2002) [2, 24].

Table 3: Effect of maize based intercropping system on *Cyperus rotundus* dry weight (g m^{-2})

Treatments	20 DAS (g m^{-2})	40 DAS (g m^{-2})	60 DAS (g m^{-2})
T_1-Maize as Sole crop	84.19 (9.23)	56.21 (7.56)	41.23 (6.50)
T_2-Cowpea + Maize at (4:1) ratio	112.27 (10.64)	59.23 (7.76)	46.56 (6.97)
T_3-Cowpea as Sole crop	195.71 (14.02)	138.12 (11.79)	121.27 (11.05)
T_4-Sorghum + Maize at (4:1) ratio	112.01 (10.63)	62.03 (7.94)	52.61 (7.32)
T_5-Sorghum as Sole crop	161.27 (12.74)	97.82 (9.94)	83.11 (9.17)
T_6-Pearl millet + Maize at (4:1) ratio	191.27 (13.86)	132.58 (11.56)	113.46 (10.70)
T_7-Pearl millet as Sole crop	231.31 (15.24)	186.67 (13.70)	156.27 (12.54)
T_8-Application of herbicide glyphosate @ 1.5-2.0 kg/ha in maize field	81.31 (9.07)	9.33 (3.11)	13.63 (3.82)
T_9-Control (open field without crop and treatment)	278.63 (16.72)	256.04 (16.03)	257.02 (16.06)
S.Ed	0.52	0.41	0.38
CD (p=0.05)	1.10	0.88	0.81

DAS - Days after sowing, Data in parentheses are $\sqrt{x}$+0.5 transformed value

Effect of maize based intercropping system on nutrients uptake by *Cyperus rotundus* (kg ha^{-1})

The uptake of nitrogen, phosphorus and potassium by *Cyperus rotundus* varied significantly with different maize based intercropping system. Among the different intercropping system, the applications of glyphosate at 1.5 to 2.0 kg ha-1 in maize field (3.40, 1.25 and 3.77 NPK kg ha^{-1}) and (4.13, 2.07 and 7.23 NPK kg ha $^{-1}$) at 40 and 60 days after sowing respectively (Table 4). This was followed by maize as a sole crop and cowpea with maize at 4:1 proportion. The nutrient uptake by *Cyperus rotundus* is a function of total dry matter production and nutrient concentration present in the weeds. The higher the purple nutsedge dry weight, the higher was the nutrient removal by *Cyperus rotundus*. The reduction of nutrients removal by *Cyperus rotundus* was associated with application of glyphosate and maize based intercropping

system. This result findings supported with Mandal *et al*. (2015) [15]. The higher uptake of nutrients under control (open field without any crop and treatment) due to high weed density and more weed dry weight accumulation. Sharma *et al*. (2008) [23] also observed nutrients competition by weeds and it was lowered by weed control treatments.

Table 4: Effect of maize based intercropping system on nutrients uptake by *Cyperus rotundus* (kg ha^{-1})

Treatments	40 DAS			60 DAS		
	Nitrogen kg ha^{-1}	Phosphorus kg ha^{-1}	Potassium kg ha^{-1}	Nitrogen kg ha^{-1}	Phosphorus kg ha^{-1}	Potassium kg ha^{-1}
T_1-Maize as Sole crop	20.61	11.18	22.97	14.77	7.43	15.22
T_2-Cowpea + Maize at (4:1) ratio	21.54	11.76	23.45	15.13	7.69	15.71
T_3-Cowpea as Sole crop	36.17	19.46	36.11	28.87	14.23	23.87
T_4-Sorghum + Maize at (4:1) ratio	21.72	11.97	23.76	15.46	7.91	15.83
T_5-Sorghum as Sole crop	28.31	15.79	28.83	22.37	10.12	19.32
T_6-Pearl millet + Maize at (4:1) ratio	35.63	18.83	35.21	27.98	13.82	23.12
T_7-Pearl millet as Sole crop	44.67	26.74	47.39	36.76	18.87	28.75
T_8-Application of herbicide glyphosate @ 1.5-2.0 kg/ha in maize field	3.40	1.25	3.77	4.13	2.07	7.23
T_9-Control (open field without crop and treatment)	64.86	33.63	66.74	61.21	29.79	67.72
S.Ed	20.61	0.40	0.77	0.61	0.30	0.61
CD (p=0.05)	21.54	0.85	1.63	1.31	0.65	1.30

DAS - Days after sowing

Effect of maize based intercropping system on weed control efficiency

Weed control efficiency (WCE) indicate the magnitude of effective reduction of weed population as well as weed dry weight by weed control treatments over control (open field without any crop and treatment immersed). Application of glyphosate at 1.5 – 2.0 kg ha^{-1} in maize field was recorded the highest weed control efficiency of 62.83 percent, 95.15 percent and 91.46 percent on 20, 40 and 60 days after sowing. This was followed by cowpea with maize at 4:1ratio and maize as a sole crop recorded the WCE of 62.17, 67.06, 73.63 and 52.28, 62.72, 71.08 percent on 20, 40 and 60 DAS (Table 5). The result revealed that application of glyphosate at 1.5 to 2.0 kg ha^{-1} was efficient method of weed management include *Cyperus rotundus*. Glyphosate used to manage weeds such as purple nutsedge minimize the injuring of crop. It is likely that glyphosate will play an important role in managing purple nutsedge in different crops (Bariuan *et al*., 1999 and Edenfield *et al*., 2005) [4, 7]. The second highest value registered for cowpea with maize at 4:1 ratio and maize as a sole crop. Maize as an allelopathic crop to release various allelochemicals on roots, stem and leaf. This allelochemicals used for suppress the weed growth and cowpea as a smoother crop to cover the large area, so ultimately to reduce the light interception for *Cyperus rotundus* (Sardana *et al*., 2017 and Jabran K, 2017) [21, 11].

Table 5: Effect of maize based intercropping system on weed control efficiency

Treatments	20 DAS (%)	40 DAS (%)	60 DAS (%)
T_1-Maize as Sole crop	62.17	67.06	73.63
T_2-Cowpea + Maize at (4:1) ratio	52.28	62.72	71.08
T_3-Cowpea as Sole crop	27.78	36.41	46.71
T_4-Sorghum + Maize at (4:1) ratio	51.12	60.74	68.90
T_5-Sorghum as Sole crop	40.83	51.84	60.95
T_6-Pearl millet + Maize at (4:1) ratio	29.72	39.47	48.97
T_7-Pearl millet as Sole crop	14.50	17.62	30.18
T_8-Application of herbicide glyphosate @ 1.5-2.0 kg/ha in maize field	62.83	95.15	91.46
T_9-Control (open field without crop and treatment)	-	-	-

DAS - Days after sowing

Conclusion

The result of the study show that applying 1.5-2.0 kg ha^{-1} of glyphosate to a maize field reduces the density, height, nutrient uptake and dry weight of *Cyperus rotundus*, also achieved good weed control efficiency. The weed control efficiency of maize as a sole crop and cowpea with maize intercropping system was similarly good, although not as high as that of the glyphosate-treated plot. However, because repeated use of glyphosate has negative consequences for the environment and soil health, the holistic approach of a maize-based intercropping system is the best practice for controlling *Cyperous rotundus*, according to several parameters that were closely monitored in the glyphosate-treated plots.

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