ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2710-6012 (Online)
CODEN: JWBMAO

Journal of Wastes and Biomass Management (JWBM)

DOI: http://doi.org/10.26480/jwbm.02.2022.111.115

CrossMark

RESEARCH ARTICLE

SPOUTING BEHAVIOUR OF WEEDS THROUGH MULCH MATERIALS AND THEIR NON-CHEMICAL MANAGEMENT IN CHILI (*CAPSICUM ANNUUM* L.)

Iswar Chandra Barua[a*], Jayanta Deka[a], Kalpana Gogoi[b], Harihar Bayan[c], Hemen Kalita[d], Ranjita Bezbaruah[e]

[a]Assam Agricultural University, Jorhat-785013
[b]Department of Agriculture, Govt. of Assam, Sonari, Charaidew-785690
[c]Biswanath College of Agriculture, AAU, Biswanath Chariali-784176
[d]Regional Agricultural Research Station, AAU, Shillongoni-782002
[d]Horticultural Research Station, AAU, Guwahati-781017
[*]Corresponding author email: iswar.c.barua@aau.ac.in

ARTICLE DETAILS

Article History:

Received 10 October 2022
Revised 14 November 2022
Accepted 16 December 2022
Available online 21 December 2022

ABSTRACT

With an aim to develop non-chemical weed management practices for green chili, an experiment was conducted at Jorhat, Assam, during 2017-19 and multi-location trials during 2020-21. Altogether seven non-chemical treatments were tested with the recommended herbicide and control. The results revealed that weeds successfully sprouted through mulch materials. Weed Control Efficiency and Weed Control Index were above 80% under Biodegradable Plastic Film (BPF) mulching and stale-seedbed treatments. The yield loss caused by the competitive weeds varied from 53.74% to 84.66%. Use of (i) rice straw mulching followed by one hand weeding at 75 DAP and (ii) BPF mulching emerged as superior non-chemical techniques of weed management resulting in better crop growth and yield. Rice-straw mulching followed by one Hand Weeding yielded as much as 6.45% more green chili than BPF mulching, 17.43% more than mechanical weeding thrice and 23.83% more than the application of herbicide.

KEYWORDS

Weeds, infestation, management, green chili.

1. INTRODUCTION

Chili (*Capsicum annuum* L., Solanaceae family), a Tropical American crop, is believed to be a gift of "Columbian Exchange" to the Old World, now being grown in most parts of the tropics, subtropics and warm-temperate countries for its diverse utilities as a spice, condiment, culinary supplement, medicine, vegetable and ornamental plant (Anon., 2009). India is the global leader in chili production with as much as 38% contribution, capturing 50% of World's export volume (FAO: Commodity Info Service, 2020). Owing to inherent characteristics of chili, such as upright nature of the plant, wide spaced branches, slow initial growth and smaller canopies, weeds offer severe competition throughout the crop growth. A group researchers estimated that the extent of reduction in fruit yield of chili by weeds is in the range of 60-70% depending on intensity and persistence of weed density in standing crops (Khan et al., 2012). The most fascinating fact is that the crop characteristics and weed attributes are not sufficient to determine the crop weed competition; these features are always and highly influenced by several edaphic, climatic and other environmental factors including human intervention (Barua and Deka, 2016).

Citing APEDA's data, some researchers have enlisted as many as 145 numbers of pesticides and heavy metals in green chili in India (Gondalia et al., 2017). Moreover, a good number of herbicides are in use in India both for transplanted and direct sown chili crop (Anon., 2022; Krishnamurthy et al., 2020). There is growing awareness against chemical pollution, coupled with increasing attractions towards the chance of market access and added value by the organic products. Organic agriculture is gaining popularity day-by-day, especially in the north-eastern region of India (NER), including chili. Two statements made by Kilcher about organic agriculture are worth mentioned here - (i) Organic agriculture reduces the risk of yield failure, stabilizes returns and improves the quality of life of small farmers' families; and (ii) Central to organic agriculture are promotion of soil fertility, biodiversity conservation (e.g. native flora and fauna), production methods adapted to the locally and avoidance of chemical inputs (Kilcher, 2007).

Out of the all-crop management factors for which chemicals are commonly used, weed is one of the global problems that cause huge losses in chili. Working on critical period of weed control in transplanted chili pepper, Amador-Ramirez stated that the crop required an average of 12.2 weeks of weed-free maintenance to avoid losses above 5% (Amador-Ramirez, 2002). Control of weeds is vitally important not only to check the losses caused by them but also to increase the input use efficiency. Observing a critical gap in organic weed management in chili cultivation, a study was undertaken to develop a suitable non-chemical practice for green chili to manage weeds effectively maintaining environmental safety and sustainability, ascertaining better growth and yield of the crop.

2. MATERIALS AND METHODS

2.1 Location and Experimental Layout

The experiment was carried out during three consecutive years (2017 to 2019) in rainfed condition at AAU, Jorhat [26°45′N latitude and 94°12′E longitude and elevation of 87 m above MSL], under the Upper Brahmaputra Valley (UBV) Agro-climatic zone. In 2020 and 2021, multi-location trials were conducted in three Agro-climatic zones of Assam, viz. the Lower (LBV) and Central Brahmaputra Valley (CBV) and North-Bank Plains (NBP). All the locations come under sub-tropical humid type of

Quick Response Code	Access this article online	
	Website: www.jwbm.com.my	**DOI:** 10.26480/jwbm.02.2022.111.115

Cite the Article: Iswar Chandra Barua, Jayanta Deka, Kalpana Gogoi, Harihar Bayan, Hemen Kalita, Ranjita Bezbaruah (2022). Spouting Behaviour of Weeds Through Mulch Materials and Their Non-Chemical Management in Chili (*Capsicum Annuum* L.). *Journal of Wastes and Biomass Management, 4(2): 111-115.*

climate. The average monthly rainfall in Jorhat during chili growing period ranged from almost 0 cm in December to around 50 cm in May (Figure 1), and the atmospheric temperature ranged from min. 10° C (Dec.) to max. 30° C (May). The experimental soil was well drained and sandy loam in texture, having pH around 5.6. The experiment was laid out in a randomized block design with nine treatments replicated thrice.

The treatments comprised of : T_1: Biodegradable black plastic film (BPF) mulching; T_2 : Rice straw (RS) mulching; T_3 : RS mulching followed by (fb) one hand weeding (HW) at 75 days after planting (DAP); T_4 : Stale seedbed; T_5 : Stale seedbed fb one HW at 75 DAP; T_6 : Mechanical weeding twice (25 and 50 DAP); T_7 : Mechanical weeding thrice (25, 50 & 75 DAP); T_8 : Recommended herbicide (Metribuzine @0.50 kg/ha as pre emergence); T_9 : Weedy. The Biodegradable black plastic film is a mixture of bio-based polymers and plasticizers (as additive) which has ability of about 90% biodegradation within 2 years and is a good candidate for sustainable organic mulches to replace polythene (PE) mulches (Miles et al., 2017). *Rice straw (RS), a readily available material for the farmers of Assam is tested in this experiment @ 2 to 2.5 kg (dry)/m² as organic mulch. For stale seedbed in this experiment, prepared* plots were covered with transparent plastic film mulch for two weeks and emerged weeds were eradicated manually before planting.

2.2 Planting and Experimental Procedure

The experimental field was initially ploughed by tractor drawn disc plough and subsequently harrowing was done by rotovator three weeks before planting. Laddering and levelling were done before laying out the experiment. Stubbles and un-decomposed weeds were removed during land preparation. Finally the field was laid out into plots with raised beds as per design. The beds assigned for treatment T_1 was covered with BPF sheet making round holes of 10-12 cm diameter at a distance of 45 cm x 45 cm; planting was done at the holes. Required quantity of chopped paddy straw was spread over the beds for the treatments T_2 and T_3. For the treatments T_4 and T_5, stale seedbeds were prepared as stated before. Metribuzine, as pre-emergence herbicide was applied for the treatment T_8 after two days of transplanting with Knapsack manual sprayer having flat fan nozzle.

The dry land weeder was manually operated in between the rows at 25, 50 and 75 days after transplanting according to the treatments T_6 and T_7. The seedlings (28 days old) of chili variety 'Suryamukhi' during 2017 and 2018 and the traditional variety '*Tezpuriya local*' in 2019 were transplanted during late November to December with a spacing of 45 cm between row to row and plant to plant. The other operations were also carried out as per the package of practices. In the multi-location trials (MLT), T_1 (BPF mulching) and T_3 (RS mulching fb HW at 75 DAP) were tested, as these two treatments gave much promising results in the experiment conducted at Jorhat. Considering the farmers' preferences, chili variety 'Krishna' was planted in NBP zone on 22 November 2019, var. 'Tejaswini' in CBV zone on 11 January 2020 and a local variety was planted in LBV zone on 12 January 2021.

2.3 Data Collection and Analysis

The observations for different characters related to weed and crop were recorded at specified time. The results of weed population and weed dry weight of all the three years were pooled. Weed Control Efficiency and Weed Control Index were calculated by following as follows (Das et al., 2016):

Weedy Control Efficiency = $[(WD_C - WD_T) \times 100] / WD_C$

Weed Control Index = $[(WDM_C - WDM_T) \times 100] / WDM_C$

Where, WD_C is the weed density (number/m²) in control plot; WD_T is the weed density in treated plot; WDM_C is the weed dry matter (g/m²) in control plot and WDM_T is the weed dry matter in treated plots.

Approved package of practices for cultivation were followed and ultimately BC ratio was computed. The identity of the weeds was authenticated at the "Weed Herbarium" of Assam Agricultural University, Jorhat. All the data pertaining to the present investigation wherever needed were statistically analysed for Randomized Block Design (RBD) as described by (Panse and Sukhatme, 1985). Critical differences (CD) at 5 per cent probability level was calculated only when the F value was found to be significant. The data on weed density and weed dry matter weight were subjected to $\sqrt{x + 0.5}$ transformation before statistically analysing them. The Standard Error of the difference was calculated by using the following expression:

$$S.Ed (\pm) = \sqrt{\frac{2 \text{ x Error Mean Square}}{\text{Number of Replication}}}$$

The Critical difference (CD) was calculated to find out the significance of mean difference amongst treatment by following formula:

CD = S.Ed (±) x $\mathbf{t_{0.05}}$ for error d.f.,

Where $t_{0.05}$ for error degree of freedom (d.f.) = table value of 't' at 5 per cent probability level for appropriate error d.f.

3. Results and Discussion

3.1 Effect of Weed Management Practices on Weed Flora Composition (Table 1 And 4):

There were altogether 31 numbers of dominant weed species during 2017 to 2019, which included 22 numbers of broadleaved weeds (BLW), 7 grasses and 2 sedges. As per Raunkiaer's system (1934) of life forms, the therophytic (TH), phanerophytic (PP) and geophytic (GP) weeds recorded during experimentation were 16, 2 and 4 numbers, respectively, and rest 9 species were with creeping behaviour belonging to chamaephytes (CH, 6) and hemicryptophyte (HC, 3). As many as 21 number of weed species were recorded when the experiment was started in 2017, however, total weed taxa became 26 in 2019. Taxa which were disappeared in the experimental field in between these years were *Cyperus rotundus, Scoparia dulcis* and *Senna alata*, while weed species which have appeared in the field after 2017 were *Alternanthera sessilis, Chenopodium album, Cleome rutidosperma, Isachne globosa, Mimosa diplotricha* var. *inermis, Oxalis debilis, Physalis minima* and *Setaria pumila.* Germination of dormant seeds present in the soil seed bank and migration of seeds from seed-sources of nearby places and their preference of the chili crop environment might be the reasons of addition of weed species during the course of experimentation. Interestingly, there was no change in composition of hemicryptophytic weed species. The adaptations of weed flora recorded in different treatments are as follows (Figure 1).

3.1.1 BPF Mulching (T_1)

Some weed species were very successful in emerging through the holes of BPF sheet made for planting of the crop seedling. The weeds recorded at 45DAP were *Panicum repens* (GP), *Polygonum plebeium* (CH) and *Cyperus-Digitaria-Paspalum* complex (HC), and at 75 DAP all the recorded weeds were CH (e.g. *Ageratum houstonianum, Spermacocce hispida* and *Isachne globosa*).

3.1.2 RS Mulching (T_2 and T_3)

Geophytes *Panicum repens* and *Alternanthera philoxeroides* were the most successful sprout-up species penetrating the RS mulch material applied in the field and their appearance was visible after 30 DAP. High energy stored in their rhizomatous stem system obviously helped their regenerating shoots in emerging through the mulch materials. The cumulative density of geophytes varied from 6.67/m² to 61.33/m² during 45 DAP; other weeds which appeared in these plots at 45 DAP were chamaephytes and hemicryptophytes. Successful therophytes at 45 DAP were *Crassocephalum crepedioides, Cyperus distans* and *Phyllanthus fraternus.* Use of 2 to 2.5 kg rice-straw (dry weight)/m² was found to be effective in suppressing almost all weeds up to 30 DAP. Lately sprout-up weeds took the advantage of withering RS mulch materials. One hand weeding at 75 DAP, however, helped in lowering the weed pressure rather considerably in the field. Thinner population of weeds and restriction in anchoring through roots because of mulch materials made hand pulling much easier.

3.1.3 Stale Seed Bed (T4 and T5)

The plots remained weed free at 45 DAP in 2019, though, geophytes like *Panicum repens, Alternanthera philoxeroides* and *Cyperus rotundus* were dominant with 33.33/m² to 68/m² density in 2017. In 2017 and 2018, other weed species recorded at 45 DAP in these plots were chamaephytes like *Ageratum houstonianum, Commelina diffusa* and hemicryptophytes belonged to *Digitaria-Paspalum* complex, along with few therophytes. The use of transparent polythene sheets for early emergence of the weeds followed by complete eradication of emerged weeds during land preparation has proved its effectiveness in complete elimination of *Cyperus rotundus* and delayed emergence (75 DAP) of *Cynodon dactylon*. Continuity of Stale-Seed-Bed technique consecutively for three years since 2017 remarkably exhausted the soil seed bank, which was reflected in zero population of emerged weeds up to 45 DAP in 2019.

3.1.4 Mechanical Weeding (T_6 and T_7)

Working with dryland weeder at 25 DAP has lowered the early emerged weed population; however, at 45 DAP, most of the weed species were reappeared. There was progressive build up of creeping weed (hemicryptophytes and chamaephytes) population, in contrary to geophytes and therophytes under mechanical weeding operations (Figure 1). The cumulative density of all creeping weeds was 142.67, 160.00 and 187.99 in the plots that received mechanical weeding twice, and 49.33, 142.66 and 177.34 in the plots that received mechanical weeding thrice, at 45, 75 and 110 DAP, respectively.

3.1.5 Metribuzine Application (T8)

Pre-emergence application of Metribuzine considerably reduced weed population; but, did not affect *Panicum repens* (GP). It lowered the weed density, especially of the therophytes; the density of geophytes and creepers under this treatment was 24 and 16 in 2017 and 41.33 and 49.33 in 2019, respectively, at 45DAP.

3.2 Weed Control Efficiency (WCE) and Weed Control Index (WCI) (Table-2)

The results revealed that creeping weeds belonging to chamaephyte and hemicryptophyte life-forms revealed high degree of positive correlation with soil moisture in the experimental site, while the geophytes expressed least degree and many a times negative correlation. It indicated that soil moisture conserved due to mulching and other management practices encouraged population build-up of chamaephytic and hemicryptophytic weeds but discouraged the growth and development of geophytic species (Figure 2 and Table 5). The population density and dry weight of weeds were the lowest at all the stages of observation under the treatment with BPF mulching. Stale seedbed technique also possessed similar weed density and dry weight as that of BPF mulching up to 45 DAP.

Table 1: List of Chilies Associated Weed Species in The Experimental Site During 2017-19

Species Name	Family	Rooting	Life Form	Habit	2017	2018	2019
BROAD-LEAVEDS							
Acmella ciliata (Kunth) Cass.	Asteraceae	DR	TH	P		√	√
Ageratum houstonianum Mill.	Asteraceae	SR	CH	P	√	√	√
Alternanthera philoxeroides (Mart.) Griseb.	Amaranthaceae	DR	GP	P	√	√	√
Alternanthera sessilis (L.) R.Br. ex DC.	Amaranthaceae	SR	CH	P		√	√
Chenopodium album L.	Chenopodiaceae	SR	TH	A		√	√
Cleome rutidosperma DC.	Cleomaceae	SR	TH	A		√	√
Commelina diffusa Burm.f.	Commelinaceae	SR	CH	P	√	√	√
Crassocephalum crepidioides (Benth.) S.Moore	Asteraceae	SR	TH	A	√	√	√
Cuphea carthagenensis (Jacq.) J.F.Macbr.	Lythraceae	DR	TH	A	√	√	√
Impatiens tripetala Roxb. ex DC.	Balsaminaceae	SR	TH	A			√
Melochia corchorifolia L.	Malvaceae	DR	TH	A	√	√	
Mimosa diplotricha Sauvalle var. diplothicha	Mimosaceae	DR	PH	A	√	√	√
Mimosa diplotricha var. *inermis* (Adelb.) M.K. Alam & M. Yusof	Mimosaceae	DR	PH	A			√
Oxalis debilis Kunth	Oxalidaceae	DR	GP	P		√	√
Phyllanthus fraternus G.L.Webster	Phyllanthaceae	SR	TH	A	√	√	√
Physalis minima L.	Solanaceae	DR	TH	A		√	√
Polygonum viscosum Buch.-Ham. ex D. Don	Polygonaceae	SR	TH	A	√		
Polygonum plebeium R.Br.	Polygonaceae	SR	CH	A	√	√	√
Rorippa dubia (Pers.) H.Hara	Brassicaceae	SR	TH	A	√	√	√
Scoparia dulcis L.	Plantaginaceae	DR	TH	A	√		
Senna tora (L.) Roxb.	Caesalpiniaceae	DR	TH	A	√		
Spermacoce hispida L.	Rubiaceae	SR	CH	P	√	√	√
SEDGES							
Cyperus distans L.f.	Cyperaceae	SR	TH	A	√	√	√
Cyperus rotundus L.	Cyperaceae	DR	GP	P	√	√	
GRASSES							
Cynodon dactylon (L.) Pers.	Poaceae	SR	HC	P	√	√	√
Digitaria setigera Roth	Poaceae	DR	HC	A	√	√	√
Eleusine indica (L.) Gaertn.	Poaceae	DR	TH	A	√	√	√
Isachne globosa (Thunb.) Kuntze	Poaceae	SR	CH	A			√
Panicum repens L.	Poaceae	DR	GP	P	√	√	√
Paspalum conjugatum P.J.Bergius	Poaceae	DR	HC	P	√	√	√
Setaria pumila (Poir.) Roem. & Schult.	Poaceae	DR	TH	A		√	√

NB: DR=Deep rooted; SR=Shallow rooted: GP=Geophyte; HC=Hemicryptophyte; CH=Chamaephyte; TH= Therophyte; PH= Phanerophyte: A= Annual; P= Perennial

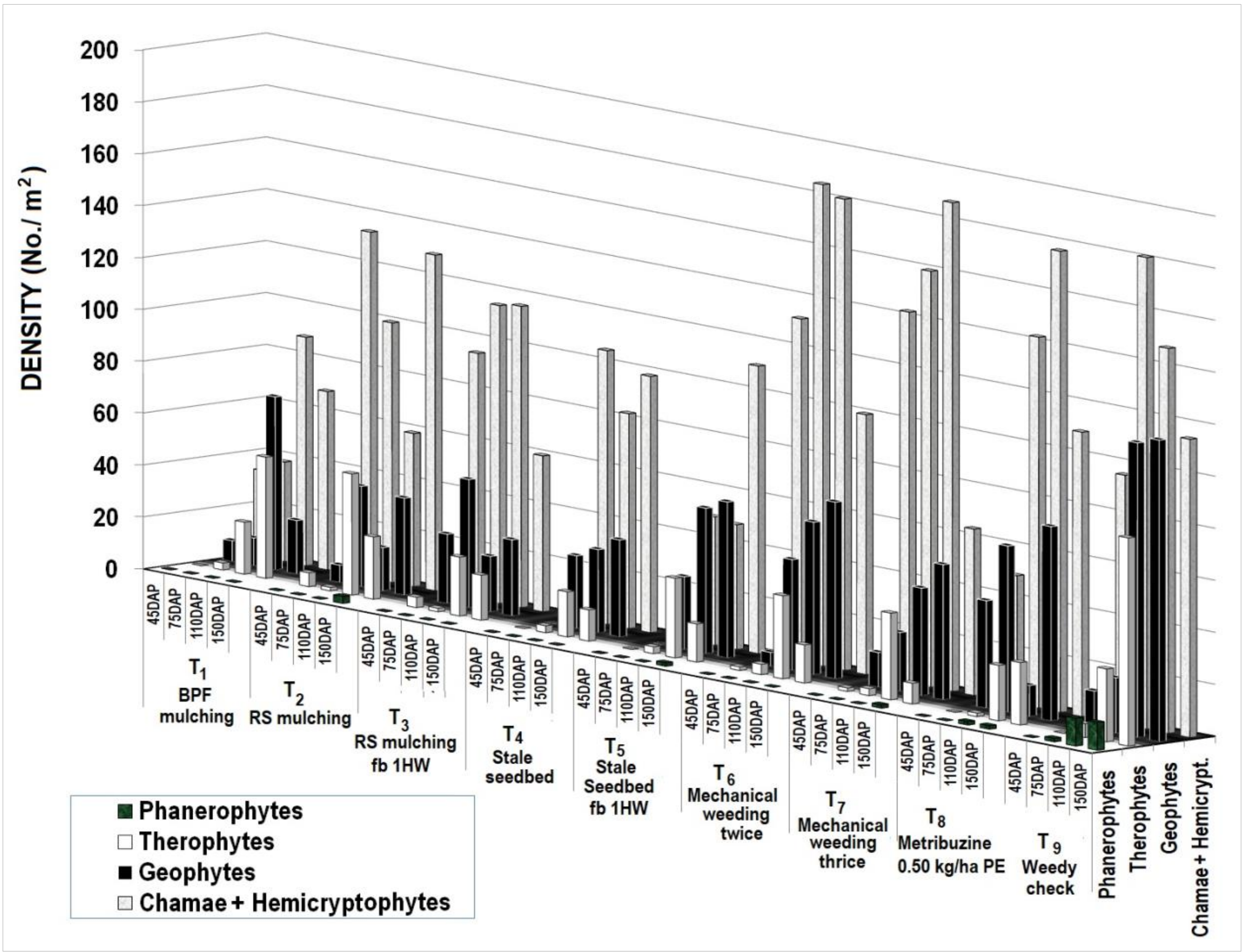

Figure 1: Effect of weed management treatments on life form wise cumulative weed density at different crop growth stages in 2019

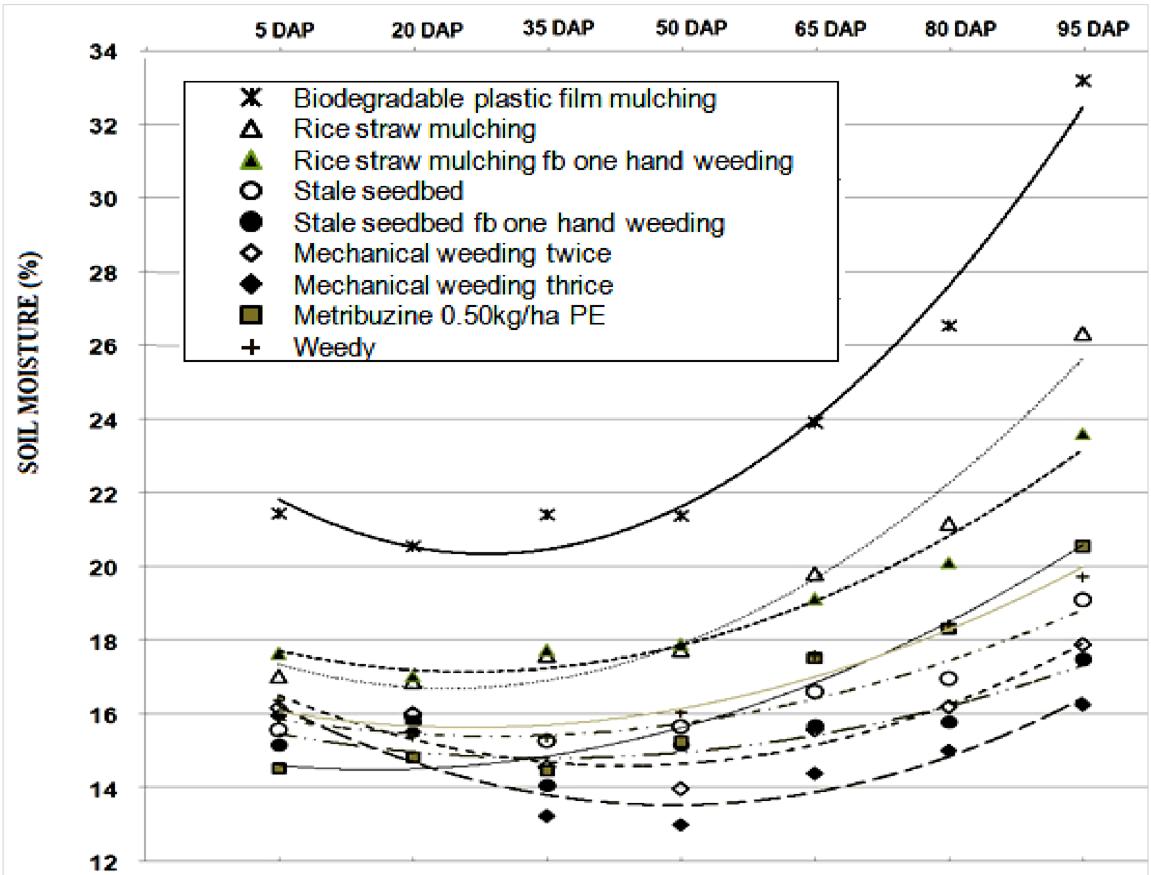

Figure 2: Effect of weed management treatments on soil moisture during chili cropping period (mean of 2017, 2018 and 2019)

Table 2: Effect of Weed Management Treatments on Weed Density and Dry Weight of Chili (Pooled Values Of 2017, 2018 And 2019) in Upper Brahmaputra Valley Agro-Climatic Zone of Assam

Treatments	Weed population density* (No./m²)			Weed Control Efficiency			Weed dry weight* (g./m²)			Weed Control Index		
	45DAP	75DAP	110DAP	45DAP	75DAP	110 DAP	45DAP	75DAP	110DAP	45DAP	75DAP	110DAP
T_1: Biodegradable plastic film mulching	4.87 (23.22)	7.32 (53.08)	7.53 (56.20)	83.55	52.09	60.51	1.57 (1.96)	3.64 (12.75)	3.92 (14.87)	89.08	68.98	74.85
T_2: Rice straw mulching	8.70 (75.19)	9.45 (88.80)	9.90 (97.51)	46.72	19.85	31.48	3.16 (9.49)	4.41 18.95)	5.79 33.02)	47.27	53.90	44.12
T_3: Rice straw mulching fb one hand weeding at 75 DAP	8.43 (70.56)	7.81 (60.50)	8.41 (70.23)	49.99	45.40	50.65	2.86 (7.68)	4.27 (17.73)	5.02 (24.70)	57.31	56.85	58.21
T_4: Stale seedbed	5.17 (26.23)	9.03 (81.04)	9.51 (89.94)	81.41	26.86	36.80	1.76 (2.60)	4.57 (20.38)	5.57 (30.52)	85.56	50.40	48.35
T_5: Stale seedbed fb one hand weeding at 50 DAP	5.22 (26.75)	8.07 (64.62)	8.26 (67.73)	81.04	41.67	52.41	1.61 (2.09)	4.18 (16.97)	5.32 (27.80)	88.37	58.70	52.96
T_6: Mechanical weeding twice (25 & 50 DAP)	8.64 (74.15)	9.68 (93.20)	11.05 (121.60)	47.45	15.88	14.54	3.64 (12.75)	5.18 (26.33)	6.65 (43.72)	29.13	35.93	26.02
T_7: Mechanical weeding thrice (25, 50 & 75 DAP)	7.40 (54.26)	9.76 (94.76)	10.03 (100.10)	61.55	14.48	29.66	3.08 (8.99)	4.53 (20.02)	6.59 (42.93)	50.05	51.29	27.36
T_8: Recommended herbicide (Metribuzine 0.50 kg/ha)	8.11 (65.27)	8.63 (73.98)	10.60 (111.86)	53.74	33.23	21.39	2.74 (7.01)	5.13 (25.82)	5.42 (28.88)	61.05	37.19	51.14
T_9: Weedy	11.90 (141.11)	10.55 110.80)	11.95 (142.80)	0	0	0	4.30 (17.99)	6.45 (41.10)	7.72 (59.10)	0	0	0
CD (p=0.05)	0.84	0.63	0.65				0.30	0.39	0.53			
%CV	11.63	7.41	7.09				11.61	8.83	9.75			

*Weed population density and weed dry weight values are transformed [√(x+0.5)]; originals are in perenthesis

However, at 75 DAP, the plots receiving RS mulching fb 1 HW at 75 DAP and Stale Seedbed fb 1 HW had showed much better weed suppression, which continued to 110 DAP. Weed dry weight in Metribuzin treated plots had insignificant difference with these two treatments at 110 DAP. WCE as well as WCI were above 80% under BPF mulching and Stale seedbed treatments at 45DAP. However, the consistency in WCE was recorded above 50% under BPF mulching, above 45% under rice straw mulching fb one HW, above 41% under rice straw mulching fb one HW and above 56% under Stale seedbed fb one HW throughout the crop growth period. These treatments also revealed constantly better WCI in all the stages of observation compared to other treatments. At 110 DAP, the highest WCI was recorded under BPF mulching (74.85), followed by RS mulching fb 1HW (58.21).

3.3 Growth, Yield Attributing Characters and Yield of Chili

The growth characters *viz*., plant height and number of primary and secondary branches per plant was influenced significantly by weed management practices. The plant height of chili var. *Suryamukhi* varied from 32.46 cm to 54.23 cm and that of var. *Tezpuria local* from 46.2 cm to 59.66 cm. Similarly, the number of primary branches varied from 3.43 to 6.13 and 3.73 to 5.80 in these varieties, respectively. It indicated that both the varieties were more or less of similar morphology. The local variety had comparatively more secondary branches which varied from 22.13 to 34.46, in comparison to 6.4 to 18.9 in the var. *Suryamukhi*. The results also revealed that plant height and branch development were greatly influenced by weed competition. In mulching treatments as well as the mechanical weeding at 25, 50 and 75 DAP, where weed competition was under control at least up to 70 DAP, the plant growth was profuse during 2017-18; however, in 2019, the var. *Tezpuria local*, showed the highest (59.66cm) plant height in the treatment with BPF mulching. The increased plant height in mulching treated chili plants was possible due to better availability of soil moisture and optimum soil temperature under the mulching treatments.

Both the BPF mulching and RS mulching fb 1HW were found to be the best treatments in producing the maximum number of chili fruits in all the years of experimentation. In contrast, the weedy treatment produced the least number of fruits. It meant that mulching had a positive influence in improving plant growth as well as on fruit setting in chili. These results are in conformity with the findings (Pande et al., 2005; Singh et al., 2008). The increase in number of leaves, fruit bearing nodes and fruits per plant in mulched plot was probably associated with the conservation of moisture and improved microclimate both beneath and above the soil surface favouring crop growth. Similar kind of observations with respect to yield attributing characters was also reported (Sathiyamurthy et al., 2017).

In 2017 and 2018 the highest green chili (var. *Suryamukhi*) yield was obtained in the plots that received RS mulching fb 1 HW. On the other hand, in 2019, the highest yield (var. *Tezpuria local*) was recorded under BPF mulching. The mean value indicated that, RS mulching fb. 1 HW yielded as much as 6.45% more green chili than BPF mulching, 17.43% more than mechanical weeding thrice and 23.83% more than the application of recommended herbicide. The present investigation has recorded yield loss in green chili caused by the competitive weeds to the extent of 84.66% (var. *Suryamukhi*) ranging from as low as 53.74% (var. *Tezpuria local*). The effect of weed management practices on fruit length was not distinct.

3.4 Benefit-Cost Ratio and Prospects of Organic Weed Management in Chili (Table 3)

A perusal of data indicated that the RS mulching fb 1HW resulted in the highest gross return, net return and benefit cost ratio in 2017, 2018 and 2019. Better weed control, lower input-cost and creation of ideal crop-growth environment were some of the reasons for which rice-straw mulching resulted better. The mean benefit cost ratio yielded by RS mulching fb 1HW (4.08:1) was found to be 21.43% more than the secondbest treatment i.e. mechanical weeding thrice and 27.10% more than the BPF mulching treatment. Decomposition of rice-straw substances in wet-acidic environment of Assam started around 30 days of application and considerable decomposition took place between 50 and 70 DAP. Hence, one hand weeding at 75 DAP in the RS mulching treatment reduced the weed pressure noticeably for a longer duration enhancing the crop yield. On the other hand, MLT results (Table 4) using different crop varieties revealed higher green chili yield from the plots that received BPF mulching compared to RS mulching fb 1HW in CBV, LBV and NBP Agro-climatic zones.

Table 3: Fruit Yield and Benefit-Cost Ratio of Chili as Affected by Different Treatments at Jorhat (Upper Agro-Climatic Zone), Assam

Treatments	Green Chilli Yield (kg/ha)				Benefit Cost Ratio			
	2017	**2018**	**2019**	**Mean**	**2017**	**2018**	**2019**	**Mean**
T_1: Biodegradable plastic film mulching	4210	5550	2733	4164.44	2.34	4.13	3.16	3.21
T_2: Rice straw mulching	4019	4333	1752	3368.11	2.72	3.69	2.15	2.85
T_3: Rice straw mulching fb one hand weeding at 75 DAP	5147	5760	2393	4433.22	3.76	5.21	3.28	4.08
T_4: Stale seedbed	3506	4100	1895	3167.11	1.70	3.23	2.40	2.44
T_5: Stale seedbed fb one hand weeding at 50 DAP	4048	4287	1852	3395.33	2.11	3.42	2.31	2.62
T_6: Mechanical weeding twice (25 & 50 DAP)	4164	4747	1791	3567.11	2.83	4.12	2.20	3.05
T_7: Mechanical weeding thrice (25, 50 & 75 DAP)	4181	4923	2221	3775.22	2.82	4.31	2.94	3.36
T_8: Recommended herbicide (Metribuzine 0.50 kg/ha)	3802	4417	2522	3580.22	1.72	2.16	1.99	1.96
T_9: Weedy	867	883	1264	1004.99	-0.19	-0.04	1.29	0.35
CD (p=0.05)	187	237	188	-	-	-	-	-
%CV	2.9	3.2	5.3	-	-	-	-	-

Table 4: Weed Growth, Green Chili Yield and Benefit-Cost Ratio in Multi-Location Trials (2020-21)

	North Bank Plain zone (BN College of Agriculture)		**Central Brahmaputra Valley zone** (Regional Agricultural Research Station)		**Lower Brahmaputra Valley zone** (Horticultural Research Station)	
	T_1	**T_2**	**T_1**	**T_2**	**T_1**	**T_2**
Weed density at 75 DAP (No./m^2)	0	128.3	21.8	26.2	55.0	90.0
Weed dry weight at 75 DAP (g/m^2)	0	93.8	63.1	59.0	445.9	76.6
Green chilli yield (kg/ha)	6211	5072	6258	5903	8500	5600
Benefit Cost Ratio	3.76	3.21	2.10	2.05	3.1	2.0
Most dominant weed flora:						
Grass:	*Cynodon dactylon* (L.) pers *Eleusine indica* (L.) Gaertn. *Digitaria setigera* Roth		*Cynodon dactylon* (L.) pers *Eleusine indica* (L.) Gaertn.		*Cynodon dactylon* (L.) pers *Eleusine indica* (L.) Gaertn. *Digitaria setigera* Roth	
Sedge:	*Cyperus rotundus* L.		*Cyperus rotundus* L.		*Cyperus rotundus* L.	
Broadleaveds:	*Ageratum houstonianum* Mill. *Commelina benghalensis* L.		*Ageratum houstonianum* Mill.		*Ageratum houstonianum* Mill. *Commelina benghalensis* L.	

Table 5: Correlation Between Soil Moisture and Weed Population Of Chili Under Different Weed Management Treatments

Treatments	Pearson's Correlation Coefficient		
	Chamaephytes + Hemicryptophytes	**Geophytes**	**All Weeds**
Biodegradable plastic film mulching	0.656	-0.022	0.586
Rice straw mulching	0.615	-0.053	0.547
Rice straw mulching fb one hand weeding	0.642	-0.043	0.569
Stale seedbed	0.619	0.018	0.565
Stale seedbed fb one hand weeding	0.546	-0.059	0.487
Mechanical weeding twice	0.531	0.046	0.499
Mechanical weeding thrice	0.395	-0.108	0.627
Metribuzine 0.50kg/ha pre-emergence (PE)	0.679*	0.075	0.627
Weedy	0.640	0.054	0.575

*Significant at p=0.05

A recent market analysis by Islam and Colonescu based on as many as 2814 observations (1407 pairs of price pairs) of organic-conventional foods of total 17 different categories revealed that majority of organic food products were expensive and 48.8% to 87.01% costlier than conventional ones, with an average of 62.94% (Colonescu, 2019). It indicated the assured possibilities of profit margin of organically produced green chili roughly minimum 50% more than conventional cultivation practices, on fulfilling all the needs of organic production and obtaining the approval from competent authorities.

4. Conclusion

Mulching is a good alternative to chemical and mechanical weed management practices leading to sustainable production of green chili. However, several crop-associated weeds, mostly creeping species belonging to hemi-cryptophytes and chomophytes, sprouted-up through mulch materials taking the advantage of gradual withering and gap amidst the materials. The soil moisture conserved due to mulching encouraged population build-up of such creeping weeds but discouraged geophytic species. On the basis of the experiments conducted, it is seen that the use of (i) rice straw mulching followed by one hand weeding at 75 DAPS as well as (ii) biodegradable plastic film mulching emerged as superior techniques for non-chemical weed management resulting in better growth and yield parameters of chili and proved to be much better economical weed management techniques for non-chemical chili production. Both the treatments are complementary to each other and hence, are recommended for inclusion in the package of practices for chili cultivation, especially for organic package of weed management. As there is assured possibilities of profit margin of organically produced food commodities roughly minimum 50% more than conventional cultivation practices, the present findings could help in gaining both ecological and economical sustainability in a crop like chili, where India stands as global leader in production as well as exportation.

Authors' Contributions

ICB & JD: Planning, Conceptualization, Conduction of experiment in the main centre, Supervision in all localities, Writing, editing and revision of manuscripts. KG: Data collection and Data analysis. HB, HK and RB conducted multi-location trials in different places. All authors read and approved the final manuscript.

Future Research and Shortcomings of the Study

Chili is one of the important cash crops in Assam as well as in the entire Indian subcontinent; however, because of lower quantity use, the biodegradable plastic film was scarce in the reach of rural farmers. In such a situation, efficient utilisation of rice straw for weed management provided ample scope of enhanced harvest with non-chemical approach. Small land holding is another important drawback in Assam. Hence, conversion of chili cultivation from conventional system to organic or natural agricultural system would certainly help in boosting the economy of chili farming. The present investigation is a pioneering step towards intensified research in such aspects.

Acknowledgement

Authors are thankful to the All India Coordinated Research project on weed Management (ICAR) for providing financial support and Assam Agricultural University, Jorhat, for providing facilities.

Conflict of Interest

All authors declare that there is no conflict of interest either financially or otherwise.

References

Amador-Ramirez, M.D., 2012. Critical period of weed control in transplanted chilli pepper. Weed Res., 42, Pp. 203-209. doi:10.1046/j.1365-3180.2002.00278.

Anonymous, 2009. Post-Harvest Profile of Chilli. Directorate of Marketing & Inspection. Govt of India. Nagpur. Pp. 80.

Anonymous, 2022. Chilli. www.ikisan.com/ka-chilli-water-managment.html

Barua, I.C., Deka, J., 2016. Weed invasion and management. In: Yaduraju NT, Sharma AR, Das TK, editors. Weed Science and Management. Cham: Indian Soc. Weed Sci. & Indian Soc. Agronomy, New Delhi, Pp. 271-292.

Commodity Info Service, 2020. Chilli. C. C. Commodity Info Service LLP. www.commoditiescontol.com/eagritender/staticpages/index.php?id=67

Das, T.K., Nath, C.P., Sharma, A.R., 2016. Weed Research Methodologies. In: Yaduraju NT, Sharma AR, Das TK, editors. Weed Science & Management. Cham: Indian Soc. Weed Sci. & Indian Soc. Agronomy, New Delhi, Pp. 357-374.

Gondalia, V.K., Bansal, R., Jadav, K.S., Shaikh, A.S., 2017. Export of fruits and vegetables from India: Growth, Opportunities and Challenges. Anand Argil. University, Gujarat, India. www.aau.in/sites/default/files/book2.pdf

Islam, S., Colonesu, C., 2019. Data on retail price differential between organic and conventional foods. Elsevier Data in Brief., 27, Pp. 1-6. doi: org/10.1016/j.dib.2019.104641

Khan, A., Muhammad, S., Hussain, Z., Khattak, A.M., 2012. Effect of different wed control methods on weeds and yield of chillis (*Capsicum annuum L.*). Pak. Journ. Weed Sci. Res., 18 (1), Pp. 71-78.

Kilcher, L., 2007. How organic agriculture contributes to sustainable development. JARTS Supplement, 89, Pp. 31-49.

Miles, C., Vetter, L., Ghimire, E., Hayes, D.G., 2017. Sustainability of biodegradable plastic mulches for organic and sustainable agricultural production systems. Hort. Science., 52 (1), Pp. 10-15.

Pande, K.K., Dimri, D.C., Prashant, K., 2005. Effect of various mulches on growth, yield and quality of Apple. Indian Journ. Hort., 62, Pp. 145-47.

Panse, V.G., Sukhatme, P.V., 1985. Statistical method for agricultural workers. II Edition. ICAR, New Delhi, India.

Raunkiær, 1934. The Life Forms of Plants and Statistical Plant Geography. Oxford University Press.

Sathyamurthy, V.A., Rajashree, V., Shanmugasundaram, T., Arumugam, T., 2017. Effect of different mulching on weed intensity, yield and economics in chilli (*Capsicum annuum* L.). Intern. Journ. Curr. Microbiol. Appl. Sci., 6 (3), Pp. 609-617.

Singh, A.K., Singh, S., Apparao, V.V., Meshram, D.T., 2008. Effect of mulching on soil properties, growth and yield of 'NA-7' aonla (*Emblica officinalies*) in semi-arid ecosystem. Indian Journ. Agric. Sci., 78 (3), Pp. 193-197.