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RESEARCH ARTICLE

Influence of mulch-based weed management in organic turmeric production

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ABSTRACT

A study was carried out during two consecutive years (2018-19 and 2019-20) on a loamy sand soil at Anand, Gujarat, India to study the effectiveness of mulch-based weed management in organically grown turmeric (*Curcuma longa* L.) production. The wheat straw mulch 5 t/ha applied at 0-3 days after planting (DAP) *fb* hand weeding (HW) at 30, 60 and 90 DAP and rice straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP were found equally effective in reducing weed biomass with higher weed control efficiency. Both these treatments resulted in significantly higher rhizome yield with higher net return and benefit cost ratio of 1.79 and 1.77, respectively.

Keywords: *Curcuma longa*, Organic cultivation, Mulching, Rice straw mulch, Turmeric, Weed management, Wheat straw mulch

INTRODUCTION

India is the largest producer, consumer and exporter of turmeric (*Curcuma longa* L.). It is also known as golden spice or spice of life belongs to the family Zingiberaceae. Turmeric is the second most important spices crop after chilli in India and it accounts for 78% in world production and 60% in world export (Angles *et al*. 2011). The major turmeric producing states in India are Andhra Pradesh, Orissa, Tamil Nadu, Assam, Gujarat and Maharashtra (Patel *et al*., 2012). Turmeric is a long duration crop and due to delayed emergence, slow initial growth to develop a canopy structure sufficient to compete with weeds and ample land space available due to wider spacing permit more sunlight to reach the soil provide congenial for rapid weed growth. Severe weed infestation leads to reduction in curcumin content and oil per cent. The average productivity is quite low mainly due to the severe competition with weeds for a longer period which causes yield lose up to 63.9-76.5% (Kaur *et al*. 2008). Turmeric requires a weed free condition of 70 to 160 days after planting (DAP) for better production of rhizomes (Dhanapal *et al*. 2017). Different methods are being used to manage the weeds in the turmeric. Mulching was found to reduce the weed growth considerably and enhance sprouting of rhizomes by conserving soil moisture. Application of straw mulch showed favourable effect on growth parameters and yield of turmeric as compared to no mulch which might be explained by early emergence, quick establishment of crop and higher interception of light. Moreover, soil under mulch remains loose, friable and well-aerated therefore, roots have access to adequate oxygen and enhance the microbial activity in the soil. Thus, a study was undertaken to study the effectiveness of mulch-based weed management in organically grown turmeric.

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MATERIALS AND METHODS

An experiment was carried out during 2018-19 and 2019-20 on loamy sand soil at Anand, Gujarat, India to study the effectiveness of mulch-based weed management in organic turmeric production. The soil of the experimental field was low in available nitrogen and medium in available phosphorous and high in potassium. Nine different weed management practices consisted of: rice straw mulch (PSM) 5 t/ha applied at 0-3 days after planting (DAP) followed by (*fb*) hand weeding (HW) at 30, 60 and 90 DAP; wheat straw mulch (WSM) 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP; inter-culture (IC) + HW at 30 DAP *fb* PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP; IC + HW at 30 DAP *fb* WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP; plastic mulch (0-3 DAP) *fb* HW at 20, 40 and 60 DAP; plastic mulch (0-3 DAP) *fb* HW at 30 and 60 DAP; turmeric + sun hemp intercropping *fb* HW at 30 DAP *fb* HW + mulch of sun hemp at 60 DAP *fb* HW at 90 DAP; IC *fb* HW at

20, 40, 60 and 80 DAP and weedy check. A randomized block design with three replications was used. Turmeric cv. *GNT 2* was planted on 15 and 6 June 2018 and 2019, respectively keeping distance of 45 x 20 cm by using seed rate of 2500 kg/ha rhizomes. The crop was harvested on 7 and 17 February 2019 and 2020, respectively. The crop was manured equivalent to the recommended rate of fertilizer at 100-50-50 NPK kg/ha applied through organic sources (50% recommended nitrogen from FYM and 50% from vermicompost) at the time of sowing during both the years of experimentation. The rest of the recommended package of practices was adopted to raise the crop. Weed management treatments were adopted as per the treatment wherein, mulching treatment was imposed after planting of turmeric rhizomes.

The monocot, dicot and sedges were collected from randomly selected four spots by using 0.25 m^2 iron quadrat from net plot through destructive sampling method at 30, 60 and 90 DAS and at harvest. Weeds were dried and dry weight of the weeds was recorded as weed biomass (g/m^2). Weed control efficiency (WCE) was calculated on the basis of weed biomass as per the formula suggested by Maity and Mukherjee (2011). Other observation was also recorded from net plot area. Benefit cost ratio was workout based on the gross realization/cost of cultivation following standard procedures.

RESULTS AND DISCUSSION

Weed flora

In the experimental field monocot weeds were dominant during both the year of experimentation. The major weeds observed in the experimental field were *Eleusine indica* (23.9%), *Dactyloctenium aegyptium* (22.6 %), *Digitaria sanguinalis* (9.87%) amongst monocot weeds whereas, *Oldenlandia umbellate* (7.02%), *Digera arvensis* (6.58%), *Phyllanthus niruri* (5.48%), *Trianthema monogyna* (5.26%) amongst dicot weeds. A sedge *Cyperus rotundus* was observed in the field.

Effect on weeds

The biomass of monocot, dicot and total weeds was significantly altered due to different weed management treatments during both the years as well as in pooled analysis however, the sedge was not influenced significantly as per pooled results (**Table 1**). Among the weed management treatments, plastic mulching (0-3 DAP) *fb* HW at 20, 40 and 60 DAP resulted in significantly lower biomass of monocots (2.59 g/m^2), dicots (1.71 g/m^2) and total weeds (3.12 g/m^2) at 30 DAP as compared to rest of the treatments except application of rice straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP and intercropping (IC) *fb* HW at 20, 40, 60 and 80 DAP. Different mulches restricted the penetration of solar radiation to soil surface leading to hampering the germination and emergence of weeds thereby biomass of weed and increased the weed control efficiency as observed by Choudhary *et al*. (2020) in ginger.

At 60 DAP, IC *fb* HW at 20, 40, 60 and 80 DAP resulted in significantly lower biomass of monocot weeds (4.49 g/m^2) as compared to weedy check; IC *fb* HW at 30 DAP + WSM 5 t/ha (0-3 DAP) *fb* HW at 60 and 90 DAP and plastic mulch (0-3 DAP) *fb* HW at 30 and 60 DAP (**Table 2**). However, IC *fb* HW at 30 DAP + WSM 5 t/ha (0-3 DAP) *fb* HW at 60 and 90 DAP caused significantly lower biomass of dicot weeds (4.14 g/m^2) and it was at par with IC *fb* HW at 30 DAP + PSM 5 t/ha (0-3 DAP) *fb* HW at 60 and 90 DAP; plastic mulch (0-3 DAP) *fb* HW at 20, 40 and 60 DAP and IC *fb* HW at 20, 40, 60 and 80 DAP. The beneficial effect of mulching in controlling weeds has resulted from delayed emergence of weeds and by restricted photosynthesis of weeds due to shading by crop plants. Manhas *et al*. (2011) reported that weed density and biomass were significantly lower with 6.25 t/ha mulch than without mulch. The total weed biomass was significantly lower (6.58 g/m^2) under IC *fb* HW at 20, 40, 60 and 80 DAP as compared to plastic mulch (0-3 DAP) *fb* HW at 30 and 60 DAP, turmeric + sun hemp intercropping *fb* HW at 30 DAP *fb* HW + mulch of sun hemp at 60 DAP *fb* HW at 90 DAP and weedy check. Maximum weed control efficiency was recorded under IC *fb* HW at 20, 40, 60 and 80 DAP (87.1%) which was closely followed by plastic mulch (0-3 DAP) *fb* HW at 20, 40 and 60 DAP (85.3%) and IC *fb* HW at 30 DAP + PSM 5 t/ha (0-3 DAP) *fb* HW at 60 and 90 DAP (85.2%).

At 90 DAP, biomass of monocot, dicot, sedges and total weed was significantly influenced by different weed management treatments during both the years individually and when pooled except non-significant on sedges when pooled (**Table 3**). Among all the weed management practices, IC *fb* HW at 20, 40, 60 and 80 DAP proved effective with the lowest biomass of monocot, dicot and total weeds (1.81, 1.83 and 2.68 g/m^2, respectively) at 90 DAP. Further, all the treatments were at par with each other in influencing biomass of monocot, dicot and total weed as compared to weedy check in pooled except wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP and turmeric + sunnhemp inter cropping *fb* HW at 30 DAP *fb* HW + mulch of sunnhemp at 60 DAP *fb* HW at 90 DAP. Maximum weed control efficiency

was achieved under IC *fb* HW at 20, 40, 60 and 80 DAP (98.4%) which was followed by plastic mulch (0-3 DAP) *fb* HW at 30 and 60 DAP (87.3%) and plastic mulch (0-3 DAP) *fb* HW at 20, 40 and 60 DAP (84.0%) at 90 DAP.

Significantly lower biomass of monocot and dicot was recorded under IC + HW *fb* PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP and IC + HW + WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP, respectively. The total weed biomass was lowest

Table 1. Monocot, dicot and sedges weed biomass as influenced by weed management treatments in turmeric at 30 DAP

Treatment	Weed biomass (g/m^2)											
	Monocot			Dicot			Sedges			Total		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Rice straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP	4.01^{de} (15.1)	2.44^{d} (5.00)	3.22^{e} (10.1)	3.83^{cd} (13.7)	1.00^{e} (0.00)	2.41^{cd} (6.85)	2.49^{ab} (5.21)	1.22^{b} (0.500)	1.86 (2.86)	5.91^{d} (34.0)	2.54^{e} (5.50)	4.23^{e} (19.8)
Wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP	4.42^{d} (18.7)	4.23^{c} (16.9)	4.33^{d} (17.8)	3.62^{d} (12.2)	4.32^{d} (17.9)	3.97^{bc} (15.1)	2.27^{b} (4.16)	1.32^{ab} (0.733)	1.79 (2.45)	6.00^{d} (35.1)	6.03^{d} (35.6)	6.01^{d} (35.4)
IC + HW at 30 DAP + PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP	10.9^{a} (117)	9.48^{a} (89.0)	10.2^{a} (103)	6.01^{a} (35.2)	6.14^{ab} (37.3)	6.07^{a} (36.3)	2.74^{a} (6.52)	1.53^{a} (1.37)	2.14 (3.95)	12.7^{a} (159)	11.3^{ab} (128)	12.0^{a} (144)
IC + HW at 30 DAP + WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP	10.7^{a} (113)	9.11^{a} (82.0)	9.89^{a} (97.5)	6.09^{a} (36.8)	6.11^{abc} (36.8)	6.10^{a} (36.8)	2.72^{a} (6.57)	1.57^{a} (1.50)	2.15 (4.04)	12.5^{a} (156)	11.0^{ab} (120)	11.8^{ab} (138)
Plastic mulch (0-3 DAP) *fb* HW at 20, 40 and 60 DAP	2.93^{e} (7.59)	2.26^{d} (4.13)	2.59^{e} (5.86)	2.41^{e} (4.80)	1.00^{e} (0.00)	1.71^{d} (2.40)	1.59^{c} (1.54)	1.23^{b} (0.533)	1.41 (1.04)	3.87^{e} (14.0)	2.37^{e} (4.67)	3.12^{e} (9.34)
Plastic mulch (0-3 DAP) *fb* HW at 30 and 60 DAP	6.51^{c} (41.7)	6.71^{b} (44.3)	6.61^{c} (43.0)	4.66^{bc} (20.7)	4.95^{cd} (23.6)	4.80^{ab} (22.2)	2.72^{a} (6.44)	1.21^{b} (0.467)	1.97 (3.45)	8.34^{c} (68.9)	8.32^{c} (68.4)	8.33^{c} (68.7)
Turmeric + sun hemp intercropping *fb* HW at 30 DAP *fb* HW + mulch of sun hemp at 60 DAP *fb* HW at 90 DAP	8.67^{b} (74.9)	8.58^{a} (73.7)	8.63^{b} (74.3)	5.01^{b} (24.4)	5.18^{bcd} (26.4)	5.10^{ab} (25.4)	2.34^{ab} (4.48)	1.36^{ab} (0.867)	1.85 (2.67)	10.2^{b} (103)	10.1^{b} (101)	10.1^{b} (102)
IC *fb* HW at 20, 40, 60 and 80 DAP	2.88^{e} (7.34)	2.30^{d} (4.33)	2.59^{e} (5.84)	2.66^{e} (6.07)	1.00^{e} (0.00)	1.83^{d} (3.04)	1.54^{c} (1.38)	1.14^{b} (0.300)	1.34 (0.840)	3.97^{e} (14.8)	2.36^{e} (4.63)	3.17^{e} (9.72)
Weedy check	10.6^{a} (112)	9.62^{a} (92.7)	10.1^{a} (102)	6.74^{a} (44.6)	6.72^{a} (44.5)	6.73^{a} (44.6)	2.75^{a} (6.60)	1.58^{a} (1.53)	2.16 (4.07)	12.8^{a} (163)	11.8^{a} (139)	12.3^{a} (151)
CV%	9.9	11.0	10.4	10.0	15.1	12.6	9.8	10.4	10.3	8.5	10.6	9.5

Note: Data subjected to $(\sqrt{x+1})$ transformation. Figures in parentheses are means of original values.
*Treatment means with the letter/letters in common are not significant by Duncan's New multiple range test at 5% level of significant, DAP=days after planting, HW = hand weeding, WSM = wheat straw mulch, PSM = rice straw mulch

Table 2. Monocot, dicot and sedges weed biomass (g/m^2) as influenced by weed management practices in turmeric at 60 DAP

Treatment	Monocot			Dicot			Sedges			Total			WCE (%)
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	
Rice straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP	4.57^{cd} (20.1)	5.70^{c} (32.7)	5.14^{cd} (26.4)	5.76^{cd} (32.7)	5.98^{bcd} (35.0)	5.87^{cd} (33.9)	2.65^{ab} (6.04)	1.58^{d} (1.52)	2.12 (3.78)	7.70^{c} (58.8)	8.35^{bc} (69.2)	8.02^{bc} (64.0)	80.7
Wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP	4.83^{bcd} (22.6)	6.11^{bc} (38.0)	5.47^{bcd} (30.2)	5.23^{de} (27.1)	4.97^{cde} (23.9)	5.10^{de} (25.5)	2.29^{b} (4.34)	1.41^{cd} (1.69)	1.85 (3.02)	7.38^{cd} (54.1)	8.00^{bc} (63.6)	7.69^{bc} (58.9)	82.3
IC + HW at 30 DAP + PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP	4.65^{cd} (20.7)	6.02^{bc} (37.2)	5.34^{bcd} (29.0)	4.27^{e} (17.5)	4.26^{e} (17.6)	4.27^{ef} (17.6)	1.61^{c} (1.60)	2.10^{abc} (3.46)	1.86 (2.53)	6.37^{cd} (39.9)	7.62^{bc} (58.2)	6.99^{c} (49.1)	85.2
IC + HW at 30 DAP + WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP	4.73^{bcd} (21.6)	8.01^{b} (63.3)	6.37^{b} (42.5)	4.05^{e} (15.5)	4.23^{e} (17.1)	4.14^{f} (16.3)	1.64^{c} (1.72)	2.26^{ab} (4.23)	1.95 (2.98)	6.29^{d} (38.7)	9.25^{b} (84.6)	7.77^{bc} (61.7)	81.4
Plastic mulch (0-3 DAP) *fb* HW at 20, 40 and 60 DAP	3.75^{d} (13.1)	5.40^{c} (29.0)	4.58^{d} (21.1)	4.68^{de} (21.5)	4.84^{de} (23.5)	4.76^{ef} (22.5)	2.56^{ab} (5.61)	2.37^{a} (4.64)	2.47 (5.13)	6.39^{cd} (40.3)	7.51^{bc} (57.1)	6.95^{c} (48.7)	85.3
Plastic mulch (0-3 DAP) *fb* HW at 30 and 60 DAP	5.82^{b} (33.1)	6.50^{bc} (42.0)	6.16^{bc} (34.6)	6.71^{bc} (44.2)	6.42^{bc} (40.5)	6.57^{bc} (42.4)	2.88^{a} (7.30)	1.88^{bcd} (2.55)	2.38 (4.93)	9.23^{b} (84.7)	9.23^{b} (85.0)	9.23^{b} (84.9)	74.4
Turmeric + sun hemp intercropping *fb* HW at 30 DAP *fb* HW + mulch of sun hemp at 60 DAP *fb* HW at 90 DAP	5.07^{bc} (24.7)	5.86^{c} (34.0)	5.47^{bcd} (29.4)	7.58^{b} (56.6)	6.53^{b} (41.9)	7.05^{b} (49.3)	1.67^{c} (1.81)	2.16^{ab} (3.66)	1.91 (2.74)	9.16^{b} (83.1)	8.97^{b} (79.5)	9.06^{b} (81.3)	75.4
IC *fb* HW at 20, 40, 60 and 80 DAP	4.13^{cd} (16.2)	4.85^{c} (22.7)	4.49^{d} (19.5)	4.36^{de} (18.3)	4.45^{e} (18.9)	4.41^{ef} (18.6)	2.50^{b} (5.28)	2.17^{ab} (3.76)	2.34 (4.52)	6.37^{cd} (39.8)	6.79^{c} (45.3)	6.58^{c} (42.6)	87.1
Weedy check	14.7^{a} (217)	15.3^{a} (232)	15.0^{a} (225)	10.7^{a} (115)	9.79^{a} (95.3)	10.3^{a} (105)	1.50^{c} (1.27)	1.65^{cd} (1.74)	1.58 (1.51)	18.3^{a} (333)	18.2^{a} (329)	18.2^{a} (331)	-
CV%	9.8	14.7	13.0	12.5	13.3	12.9	9.9	12.9	11.4	8.4	9.6	9.1	-

Note: Data subjected to $(\sqrt{x+1})$ transformation. Figures in parentheses are means of original values.
*Treatment means with the letter/letters in common are not significant by Duncan's New multiple range test at 5% level of significant, DAP=days after planting, HW = hand weeding, WSM = wheat straw mulch, PSM = rice straw mulch

(8.52 g/m^2) with wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP when compared to other treatments except IC + HW at 30 DAP + PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP, PSM 5 t/ha (0-3 DAP) *fb* HW at 30, 60, 90 DAP and IC + HW at 30 DAP + WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP at harvest. The lowest weed biomass under spreading of rice and wheat straw mulch may be due

Table 3. Monocot, dicot and sedges weed biomass as influenced by weed management treatments in turmeric at 90 DAP

Treatment	Monocot			Dicot			Sedges			Total			WCE (%)
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	
Rice straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP	6.69^{b} (43.8)	6.40^{bc} (40.5)	6.55^{bc} (42.2)	4.04^{bc} (15.4)	4.95^{b} (23.8)	4.50^{b} (19.6)	1.70^{bc} (1.90)	1.87^{b} (2.53)	1.78 (2.22)	7.88^{b} (61.1)	8.20^{b} (66.8)	8.04^{b} (64.0)	83.9
Wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP	6.67^{b} (43.7)	6.99^{bc} (48.1)	6.83^{b} (45.9)	3.62^{c} (12.1)	4.62^{b} (21.6)	4.12^{b} (16.9)	1.46^{d} (1.13)	1.98^{ab} (3.09)	1.72 (2.11)	7.60^{b} (56.9)	8.58^{b} (72.8)	8.09^{b} (64.9)	83.7
IC + HW at 30 DAP + PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP	7.12^{b} (49.9)	5.79^{c} (32.8)	6.45^{bc} (41.4)	4.15^{bc} (16.5)	5.08^{b} (25.9)	4.61^{b} (21.2)	1.51^{cd} (1.28)	2.04^{ab} (3.31)	1.78 (2.30)	8.27^{b} (67.6)	7.87^{b} (62.0)	8.07^{b} (64.8)	83.7
IC + HW at 30 DAP + WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP	6.40^{b} (40.2)	6.08^{bc} (36.3)	6.24^{bc} (38.3)	4.11^{bc} (15.9)	5.44^{b} (29.4)	4.77^{b} (22.7)	1.47^{d} (1.17)	2.28^{ab} (4.20)	1.86 (2.69)	7.62^{b} (57.3)	8.42^{b} (69.9)	8.02^{b} (63.6)	84.0
Plastic mulch (0-3 DAP) *fb* HW at 20, 40 and 60 DAP	5.91^{b} (34.3)	6.37^{bc} (40.7)	6.14^{bc} (37.5)	4.13^{bc} (16.4)	5.31^{b} (28.1)	4.72^{b} (22.3)	1.87^{b} (2.50)	2.58^{a} (5.67)	2.22 (4.09)	7.32^{bc} (53.2)	8.68^{b} (74.4)	8.00^{b} (63.8)	84.0
Plastic mulch (0-3 DAP) *fb* HW at 30 and 60 DAP	4.41^{c} (18.7)	5.70^{c} (31.8)	5.06^{c} (25.3)	4.23^{bc} (17.0)	5.07^{b} (25.0)	4.65^{b} (21.0)	2.16^{a} (3.70)	2.33^{ab} (4.55)	2.25 (4.13)	6.34^{c} (39.4)	7.88^{b} (61.3)	7.11^{b} (50.4)	87.3
Turmeric + sun hemp intercropping *fb* HW at 30 DAP *fb* HW + mulch of sun hemp at 60 DAP *fb* HW at 90 DAP	6.26^{b} (38.2)	7.63^{b} (57.7)	6.94^{b} (48.0)	4.68^{b} (20.9)	5.08^{b} (25.3)	4.88^{b} (23.1)	1.46^{d} (1.14)	2.29^{ab} (4.30)	1.88 (2.72)	7.82^{b} (60.2)	9.37^{b} (87.3)	8.60^{b} (73.8)	81.4
IC *fb* HW at 20, 40, 60 and 80 DAP	1.74^{d} (2.00)	1.89^{d} (2.60)	1.81^{d} (2.30)	1.56^{d} (1.40)	2.09^{b} (3.40)	1.83^{b} (2.40)	1.44^{d} (1.09)	1.74^{b} (2.18)	1.59 (1.64)	2.35^{d} (4.60)	3.01^{c} (8.18)	2.68^{c} (6.39)	98.4
Weedy check	13.8^{a} (191)	16.0^{a} (257)	14.9^{a} (224)	15.9^{a} (254)	9.43^{a} (89.1)	12.7^{a} (172)	1.71^{bc} (1.92)	1.66^{b} (1.79)	1.69 (1.86)	21.1^{a} (447)	18.6^{a} (348)	19.9^{a} (398)	-
LSD (p=0.05)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.	-
CV%	9.8	13.3	11.8	8.8	20.4	15.8	5.8	16.7	13.7	7.5	9.3	8.5	-

Note: Data subjected to $(\sqrt{x+1})$ transformation. Figures in parentheses are means of original values.
*Treatment means with the letter/letters in common are not significant by Duncan's New multiple range test at 5% level of significant, DAP=days after planting, HW = hand weeding, WSM = wheat straw mulch, PSM = rice straw mulch

Table 4. Monocot, dicot and sedges weed biomass as influenced by weed management practices in turmeric at harvest

Treatment	Monocot			Dicot			Sedges			Total			WCE (%)
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	
Rice straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP	5.69^{e} (31.4)	7.32^{b} (52.8)	6.51^{cd} (42.1)	5.83^{def} (33.3)	6.46^{cd} (41.3)	6.15^{ef} (37.3)	1.65^{bc} (1.73)	1.59^{ab} (1.58)	1.62^{a} (1.66)	8.21^{ef} (66.5)	9.81^{de} (95.7)	9.01^{d} (81.1)	76.1
Wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP	5.31^{e} (27.5)	8.14^{b} (65.3)	6.72^{cd} (46.4)	4.66^{f} (21.1)	5.66^{d} (31.7)	5.16^{f} (26.4)	1.52^{cd} (1.33)	1.49^{b} (1.24)	1.51^{a} (1.29)	7.10^{f} (49.9)	9.94^{cde} (98.2)	8.52^{d} (74.1)	78.1
IC + HW at 30 DAP + PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP	5.27^{e} (27.7)	6.55^{b} (43.1)	5.91^{d} (35.4)	6.31^{de} (38.8)	5.58^{d} (30.7)	5.95^{ef} (34.8)	1.92^{ab} (2.70)	1.64^{ab} (1.71)	1.78^{a} (2.21)	8.36^{ef} (69.2)	8.69^{e} (75.4)	8.53^{d} (72.3)	78.7
IC + HW at 30 DAP + WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP	7.12^{de} (50.1)	7.10^{b} (51.3)	7.11^{cd} (50.7)	5.28^{ef} (27.7)	6.12^{d} (36.7)	5.70^{f} (32.2)	1.28^{d} (0.66)	1.63^{ab} (1.65)	1.46^{a} (1.16)	8.88^{e} (78.5)	9.47^{de} (89.7)	9.18^{d} (84.1)	75.2
Plastic mulch (0-3 DAP) *fb* HW at 20, 40 and 60 DAP	8.49^{cd} (71.3)	7.93^{b} (63.9)	8.21^{bc} (67.6)	8.41^{bc} (70.0)	8.19^{bc} (66.7)	8.30^{bc} (68.4)	1.52^{cd} (1.33)	1.52^{b} (1.31)	1.52^{a} (1.32)	12.0^{cd} (143)	11.5^{bcd} (132)	11.7^{bc} (138)	59.3
Plastic mulch (0-3 DAP) *fb* HW at 30 and 60 DAP	10.7^{b} (113)	9.15^{b} (83.4)	9.91^{b} (98.2)	7.09^{cd} (49.7)	8.53^{b} (72.0)	7.81^{cd} (60.9)	2.02^{a} (3.13)	1.72^{ab} (1.99)	1.87^{a} (2.56)	12.9^{bc} (166)	12.6^{bc} (157)	12.7^{bc} (162)	52.2
Turmeric + sun hemp intercropping *fb* HW at 30 DAP *fb* HW + mulch of sun hemp at 60 DAP *fb* HW at 90 DAP	10.1^{bc} (101)	9.00^{b} (86.7)	9.53^{b} (93.9)	9.52^{ab} (89.8)	8.71^{b} (76.0)	9.12^{b} (82.9)	1.27^{d} (0.62)	1.79^{ab} (2.21)	1.53^{a} (1.42)	13.9^{b} (191)	12.7^{b} (165)	13.3^{b} (178)	47.5
IC *fb* HW at 20, 40, 60 and 80 DAP	8.67^{cd} (74.4)	9.42^{b} (88.0)	9.05^{b} (81.2)	6.96^{cd} (47.9)	6.99^{bcd} (48.3)	6.98^{de} (48.1)	1.64^{c} (1.71)	1.83^{a} (2.37)	1.74^{a} (2.04)	11.2^{d} (124)	11.8^{bcd} (139)	11.5^{c} (132)	61.1
Weedy check	14.2^{a} (201)	14.0^{a} (195)	14.1^{a} (198)	11.0^{a} (122)	12.6^{a} (159)	11.8^{a} (141)	1.00^{e} (0.00)	1.00^{c} (0.00)	1.00^{b} (0.00)	18.0^{a} (323)	18.8^{a} (354)	18.4^{a} (339)	-
CV%	11.3	18.1	15.2	11.5	12.1	11.8	9.1	9.8	9.5	8.0	12.0	10.3	-

*Data subjected to $(\sqrt{x+1})$transformation. Figures in parentheses are means of original values. Treatment means with the letter/letters in common are not significant by Duncan's New multiple range test at 5% level of significant. DAP=days after planting, HW = hand weeding, WSM = wheat straw mulch, PSM = rice straw mulch

Table 5. Effect of weed management practices on plant stand, rhizome yield, weed index and economics of turmeric

Treatment	Plant stand at harvest (no./net plot)			Rhizome yield (t/ha)			Weed index (%)			Net returns (x10^3 `/ha)	Total cost of cultivation (x10^3 `/ha)	B:C
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled			
Rice straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP	144^{a}	151^{a}	148^{a}	23.4^{ab}	23.0^{a}	1.79	3.31	-	-	153.42	194.58	1.79
Wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP	145^{a}	149^{ab}	147^{a}	24.2^{a}	21.7^{ab}	1.77	-	5.80	1.29	148.92	194.58	1.77
IC + HW at 30 DAP + PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP	139^{ab}	146^{ab}	143^{ab}	19.3^{c}	18.0^{cd}	1.40	20.2	21.9	19.8	79.26	199.74	1.40
IC + HW at 30 DAP + WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP	141^{a}	143^{b}	142^{ab}	19.5^{bc}	18.9^{bc}	1.44	19.4	17.7	17.2	88.26	199.74	1.44
Plastic mulch (0-3 DAP) *fb* HW at 20, 40 and 60 DAP	124^{b}	132^{c}	128^{bc}	13.5^{de}	12.3^{ef}	0.90	44.2	46.4	44.4	-22.01	215.51	0.90
Plastic mulch (0-3 DAP) *fb* HW at 30 and 60 DAP	123^{b}	136^{c}	129^{bc}	13.1^{de}	11.2^{f}	0.85	45.9	51.4	47.8	-32.23	213.73	0.85
Turmeric + sun hemp intercropping *fb* HW at 30 DAP *fb* HW + mulch of sun hemp at 60 DAP *fb* HW at 90 DAP	124^{b}	144^{ab}	134^{b}	11.0^{e}	10.3^{f}	0.85	54.5	55.3	54.3	-27.77	186.77	0.85
IC *fb* HW at 20, 40, 60 and 80 DAP	129^{ab}	143^{b}	136^{b}	14.9^{d}	14.8^{de}	1.13	38.4	35.5	35.8	25.40	198.10	1.13
Weedy check	60.7^{c}	55.0^{d}	57.8^{d}	2.30^{f}	2.33^{g}	0.20	90.5	89.9	90.0	-139.25	173.90	0.20
CV%	6.8	2.8	5.1	13.0	11.3	12.2	-	-	-		-	

*Treatment means with the letter/letters in common are not significant by Duncan's New multiple range test at 5% level of significant.
DAP: Days after planting, HW: Hand weeding, WSM: Wheat straw mulch, PSM: Rice straw mulch

to their effective suppression of the weed growth as observed in garlic and onion (Chaudhari *et al*. 2019) and also due to maintenance of the moisture as well as congenial condition, *i.e.* optimum temperature for better growth of the crop. Amoroso *et al*. (2010) reported that mulch controls the weeds by smothering, prevent day light which helps foster germination from reaching weed seeds and prevents airborne seeds from taking hold on the soil surface. Maximum weed control efficiency was observed under IC + HW at 30 DAP + PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP which was closely followed by wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP, PSM 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP and IC + HW at 30 DAP + WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP at harvest.

Effect on turmeric and economics

The turmeric plant stand was optimal at 35 DAP during 2018-19, 2019-20 and in pooled at harvest. Significantly lower plant stand was recorded under plastic mulch (0-3 DAP) *fb* HW at 20, 40 and 60 DAP and plastic mulch (0-3 DAP) *fb* HW at 30 and 60 DAP as compared to rest of the treatment except weedy check which had significantly lowest plant stand (57.8/net plot) at harvest. Vanlalhluna *et al*. (2010) also observed beneficial effects of mulch on early sprouting of turmeric through moisture retention.

The rice straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP and wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP remaining at par with each other resulted in significantly highest rhizome yield (23.2 and 22.9 t/ha, respectively). This might be attributed to effective reduction in the weeds biomass by mulches which was indicated from the higher rhizome yield as compared to no mulch. The next better treatment in order was IC + HW at 30 DAP + PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP and IC + HW at 30 DAP + WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP which gave rhizome yield of 19.2 and 18.9 t/ha, respectively as compared to rest of the treatment. Similarly, higher yield of garlic under rice straw much was also observed by Chaudhari *et al*. (2019). Increased growth parameters and reduced weed pressure on crop has led to increase in yield as reported by Ashok and Sanjay (2014). Further. the lowest turmeric rhizome yield (2.31 t/ha) was recorded under weedy check treatment as observed by Dhanapal *et al*. (2017). Yield reduction due to presence of weed was recorded minimum under wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP (1.29%) followed by IC + HW at 30 DAP + WSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP (17.2%) and IC + HW at 30 DAP + PSM 5 t/ha (30 DAP) *fb* HW at 60 and 90 DAP (19.8%) while maximum yield reduction was observed under weedy check (90.0%) followed by turmeric + sun hemp intercropping *fb* HW at 30 DAP *fb* HW + mulch of sunnhemp at 60 DAP *fb* HW at 90 DAP (54.3%). Yield reduction of 78.2% due to weeds in weedy check was reported by Sachdeva *et al*. (2015).

Economics of different treatments indicated that maximum net returns of ` 1,53,420/ha with the highest benefit cost ratio of 1.79 was achieved under

rice straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP, which was closely followed by wheat straw mulch 5 t/ha (0-3 DAP) *fb* HW at 30, 60 and 90 DAP which has recorded net return of ₹ 1,48,920/ha with the benefit cost ratio of 1.77. Similar observations were made by Roy and Dharminder (2015).

It was concluded from this study that integration of rice straw and wheat straw as mulching 5 t/ha with HW at 30, 60 and 90 DAP provides effective control of weeds, increases turmeric rhizome yield as well as higher net return and benefit cost ratio under organic production system.

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