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Phyto-Extract-Based Weed Management in Organic Sweet Corn: A Comparative Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *kharif* 2020 and 2021 to study the weed management in organic sweet corn through phyto-extracts at the Main Agricultural Research Station, University of Agriculture Sciences, Dharwad, Karnataka. The experiment with randomized complete block design (RCBD) was laid out with fifteen treatments, comprises of four Phyto extracts of 30% concentration (*Parthenium hysterophorus, Cassia sericea, Lantana camara and Prosopis juliflora)* in combinations with directed spray of respective extract at pre-emergence, 20, 40 DAS *fb* one inter cultivation at 40 DAS *fb* hand weeding and another three treatments namely T_{13}: inter-cultivation at 20 and 40 DAS *fb* one hand weeding at 20 DAS, T_{14}: weedy check and T_{15}: weed free check. The pooled data of the experiment indicated that, inter-cultivation at 20 and 40 DAS and one hand weeding at 20 DAS recorded significantly higher the fresh cob yield (180.26 q ha^{-1}), fresh fodder yield (341.66 q ha^{-1}), net returns (Rs. 2,45,049 ha^{-1}) and B:C ratio (4.16) with higher WCE as compared to other

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treatments. Among different phyto-extract treatments with time of application, directed spray of *Parthenium hysterophorus* at 30% leaf extract at 20 DAS and one inter-cultivation at 40 DAS followed by hand weeding recorded significantly higher the fresh cob yield (159.15 q ha^{-1}), fresh fodder yield (315.13 q ha^{-1}), net returns (Rs. 2,07,914 ha^{-1}) and B:C ratio (3.66) with the higher WCE 80.40 and 68.76 per cent at 60 DAS and at harvest, respectively as compared to other phyto-extract treatments.

Keywords: Allelochemicals; phyto extracts; sweet corn; weed control efficiency; weed index.

1. INTRODUCTION

Sweet corn (*Zea mays* L. *var*. *saccharata* Sturt), a hybrid variety of corn with enhanced sugar content, is gaining popularity in upscale establishments like hotels, malls, and stores, finding use in soups, sweets, jams, and more. (Palcon et al. 2023) With the potential for 3-4 crops annually and its suitability as nutrient-rich animal fodder, sweet corn is gaining ground in India and across Asia, offering farmers an appealing option. However, weed competition for essential resources such as nutrients, water, sunlight, and space is the most critical contributor to low yields in sweet corn cultivation Javaid et al. [1] and Choudhary et al. [2] Selecting effective and economically viable weed control methods is crucial. Weed management strategies encompass various cultural, biological, and chemical approaches [3,4]. Chemical control, although prevalent, raises concerns due to excessive herbicide use, improper application techniques, and the repeated application of specific herbicide groups leading to undesirable shifts in weed populations [5,6]. Organic weed management become one of the options, which include mechanical weeding, cover cropping, crop rotation, modified sowing and planting methods, organic residue mulching, green manuring, reduced or zero tillage, soil solarization, hand weeding, intercropping and phyto-extract sprays [7,8]. These practices curtail weed seed germination and growth, thereby enhancing maize yield. Incorporating allelopathic weed extracts alone or in conjunction with herbicides effectively suppresses weed growth through various mechanisms such as photosynthesis inhibition, enzyme disruption, and cell membrane damage [9,10,11]. Allelopathic compounds released from plant parts inhibit weed development and often demonstrate selectivity akin to synthetic herbicides [12]. allelopathic potential presents a promising approach for improved weed management [13,14]. Biological control of weeds is an important method of weed control and is also environment friendly and very cheap [15]. Grassy and broad-leaf plants have the potential to suppress weed [13,14]. Allelopathic potential of safflower has been reported in several studies. Miri (2011) reported that safflower significantly inhibit the germination and root and shoot growth of wild barley (*Hordeum spontaneum* L.) and has great potential for management of this weed in wheat (*Triticum aestivum* L.) production. Farhoudi and Lee (2012) showed that safflower extracts inhibited the induction of α-amylase in wild mustard (*Sinapis arvensis* L.) seeds. Safflower has also allelopathic influence on the barley seed germination and result in less seed germination and poor growth of seedling [16]. Allelopathy is an important mechanism of plant interference mediated by the additional phytotoxins to the environment; chemicals with allelopathic potential are present in virtually all plants as in most tissues. Under appropriate conditions, these chemicals may be released into the environment, in sufficient quantities to affect neighbouring plants (Tahir, 2011). A study was conducted during kharif 2020-21 and 2021-22 at University of Agricultural Sciences, Dharwad, Karnataka to investigate "weed management in organic sweet through phyto-extracts" and seeks to contribute to sustainable weed management practices in organic sweet corn cultivation.

2. MATERIALS AND METHODS

2.1 Experimental Site and Soil Characteristics

A field experiment was carried out during *kharif* 2020 and 2021 at University of Agricultural Sciences, Dharwad, Karnataka which is situated in the Northern Transition Zone of Karnataka (Zone 8) lies 15^{o}30’6’’ North latitude, 74^o 59’12.4’’ East longitude and at an altitude of 678 m above mean sea level (MSL). The soil of the experimental site was medium deep black with a depth of 2-3 m and is well drained. The soil having neutral pH (7.12), normal electrical conductivity (0.21 dS m^{-1}), medium in soil organic carbon (5.56 g kg^{-1}), available N (287 kg ha^{-1}), available P_2O_5 (28.70 kg ha^{-1}) and K_2O (326 kg ha^{-1}).

2.2 Design of Experiment and Treatment Details

The experiment was laid randomized complete block design (RCBD) with fifteen treatments namely T_1: Directed spray of *Prosopis juliflora* at 30% leaf extract at pre-emergence, 20 and 40 DAS, T_2: Directed spray of *Prosopis juliflora* at 30% leaf extract at 20 and 40 DAS, T_3: Directed spray of *Prosopis juliflora* at 30% leaf extract at 20 DAS and one IC at 40 DAS fb. hand weeding, T_4: Directed spray of *Parthenium hysterophorus* at 30% leaf extract at pre-emergence, 20 and 40 DAS, T_5: Directed spray of *Parthenium hysterophorus* at 30% leaf extract at 20 and 40 DAS, T_6: Directed spray of *Parthenium hysterophorus* at 30% leaf extract at 20 DAS and one IC at 40 DAS fb. hand weeding, T_7: Directed spray of *Cassia sericea* at 30% leaf extract at pre-emergence, 20 and 40 DAS, T_8: Directed spray of *Cassia sericea* at 30% leaf extract at 20 and 40 DAS, T_9: Directed spray of *Cassia sericea* at 30% leaf extract at 20 DAS and one IC at 40 DAS fb. hand weeding, T_{10}: Directed spray of *Lantana camara* at 30% leaf extract at pre-emergence, 20 and 40 DAS, T_{11}: Directed spray of *Lantana camara* at 30% leaf extract at 20 and 40 DAS, T_{12}: Directed spray of *Lantana camara* at 30% leaf extract at 20 DAS and one IC at 40 DAS *fb*. hand weeding, T_{13}: Inter-cultivation at 20 and 40 DAS and one hand weeding at 20 DAS, T_{14}: Weedy check and T_{15}: Weed free check were replicated thrice. Recommended RDF for the organic maize in Karnataka is 100: 50: 25 kg ha^{-1} N: P_2O_5:K_2O. Nutrient management through recommended dose nitrogen equivalent through FYM and vermicompost each of 50 per cent (50% RDN through FYM and 50% RDN through vermicompost). Hence, FYM (9.2 t ha^{-1}) and vermicompost (4.4 t ha^{-1}) were utilized for soil application prior to 3 weeks of sowing of sweet corn. Foliar application of *panchagagvya* @ 30 liters ha^{-1} at 45 and 60 DAS. Directed spray of different phyto extracts each @ 30 per cent solution was sprayed at different interval as per the treatments, for which 750 liters spray mixture per hectare was used.

2.3 Observation and Statistical Analysis

Weeds were counted on 30, 60 DAS and at harvest. grasses, sedges and broad-leaved weeds present within 1 m × 1 m random quadrant in each net plot were counted separately and expressed as number of weeds per square meter (No. m^{-2}) and were oven dried to a constant weight at 65 °C and dry weight of weeds in each treatment was recorded and expressed as grams per square meter (g m^{-2}). Data on fresh cob yield and fresh fodder were recorded at harvest. Data on weed count and weed dry weight have shown high degree of variation. A relationship between the means and variance was observed. Therefore, the data on weed count and weed dry weight were subjected to square root of (x + 0.5) transformation to make analysis of variance more valid as suggested by Bartlett [17]. The experimental data obtained were subjected to statistical analysis by adopting Fisher's method of analysis of variances outlined by Gomez and Gomez [18]. The level of significance used in 'F' test was at 5%. The mean value subjected to Duncan's multiple range test (DMRT) using the corresponding mean sum of square and degree of freedom values using HAU-OPSTAT software [7].

3. RESULTS AND DISCUSSION

3.1 Effect of Weed Management Practices for Weed Control in Sweet Corn

The data pertaining to total weed density per square meter area (Table 1) and the total dry weight of weeds (Table 2) exhibited significant difference as influenced by different weed control treatments at all growth stages. The highest weed density was noted in the weedy check, whereas the weed-free check registered the lowest values at all the growth stages. Among the phyto-extract treatments for weed management in sweet corn, targeted spray of 30% *Parthenium hysterophorus* leaf extract at pre-emergence, 20 and 40 DAS resulted significantly lower total weed density per m^2 (6.23 and 6.20 at 15 and 30 DAS, respectively) and lower total dry weight of weeds (4.39 g m^{-2} at 15 DAS) in comparison to other treatments. At the 60 DAS and harvest stages of the sweet corn crop, the directed spray of 30% *Parthenium hysterophorus* leaf extract at 20 DAS, coupled with one inter-cultivation at 40 DAS followed by hand weeding resulted in significantly lower total weed density per m^2 (4.60 and 5.47) and lower total dry weight of weeds (5.66 and 7.75 g m^{-2} at 60 DAS and harvest, respectively), as compared to other treatments. This could be attributed to the initial control of weeds by phyto-extracts for the first 30 days, followed by weed management through inter-cultivation. Pandey [19] reported the phytotoxic nature of *Parthenium* leaf extract, impacting the cytomorphological behavior of sunflower and other crops. *Parthenium hysterophorus* leaf extract contained allelochemicals such as *parthenin, caffeic acid, vanillic acid* and *p-comeric acid. Prosopis juliflora* contained *caffeic acid, vanillic acid* and *julifloria*. *Lantana camara* contained *caffeic acid* and *tannic acid*, while *Cassia sericea* contained only *vanillic acid*. These findings are consistent with the observations of Pandey [19] and Aasifa et al*.* [20].

Phenolic compounds and the major sesquiterpene lactone parthenin exhibit toxicity towards seed germination and plant growth, impacting both terrestrial and aquatic species. This toxicity includes inhibiting seed germination, seedling growth, and overall plant development. Particularly effective weed suppression was observed at 20 DAS, possibly due to hampering germinating and early growth of weeds. *Parthenium* weed extracts contain allelochemicals like phenolic acids and parthenin, which may lead to electrolyte loss and reduced weed chlorophyll. These allelopathic effects tend to manifest early in the weed life cycle, hindering germination and seedling growth. These compounds act through various mechanisms, affecting DNA, photosynthesis, mitochondrial function, phytohormones, ion uptake, and water balance. It's noteworthy that individual compounds can have multiple phytotoxic effects. These observations align with findings by Tripathi and Vaishya [21]

In general, total dry weight of weeds and weed population increased up to 60 DAS and then gradually decreased up to harvest, indicating greater weed emergence between 30 and 60 DAS, in line with findings by Sharma and Gautam [22] and Arvadiya et al*.* [23]. The performance of the crop was directly related to weed control efficiency (Table 3) and inversely related to the weed index. Among the weed control treatments, higher weed control efficiency was achieved with inter-cultivation at 20 and 40 DAS and one hand weeding at 20 DAS (91.11, 88.15, and 77.39% at 30, 60 DAS and harvest, respectively), compared to other treatments. Similarly, among different phyto-extract treatments, applying *Parthenium hysterophorus* @ 30% leaf extract at pre-emergence, 20 and 40 DAS recorded higher weed control efficiency (51.62% at 30 DAS) and lower weed index (33.52%), while at 60 DAS and harvest stages, directed spray of *Parthenium hysterophorus* at 30% leaf extract at 20 DAS, coupled with one inter-cultivation at 40 DAS followed by hand weeding, resulted in significantly higher weed control efficiency (80.40 and 68.76% at 60 DAS and harvest, respectively) and lower weed index (22.40% at harvest), as compared to other treatments. This outcome could be attributed to effective initial weed control by 30% *Parthenium hysterophorus* leaf extract, followed by subsequent control through inter-cultivation at 40 DAS and hand weeding. These results align with findings by Eranna [24] and Thejasvi [25].

The weed index, representing yield reduction from weed competition, reached its peak in the weedy check (48.36%). This was attributed to diminished fresh cob yield, a consequence of uncontrolled weed growth competing for nutrients, moisture, space, and light, leading to poor growth and yield components [15]. Conversely, the lowest weed index was observed in inter-cultivation at 20 and 40 DAS, followed by one hand weeding (12.11%). Among various phytoextract treatments and their timing, directed spray of *Parthenium hysterophorus* @ 30% leaf extract at 20 DAS, coupled with one inter-cultivation at 40 DAS and hand weeding, exhibited a lower weed index (22.40%) as compared to other leaf extract treatments. This was mainly due to the effective control of all types of weeds at critical weed crop competition period of sweet corn. Moreover, the nutrients extracted by weeds were significantly reduced compared to the weedy check [26,27,28]. These results align with finding of Thejasvi [25].

3.2 Crop Growth and Yield of Sweet Corn

The highest fresh cob yield (205.07 q ha^{-1}) was achieved with the weed-free check. Notably, the treatment involving inter-cultivation at 20 and 40 DAS, along with one hand weeding at 20 DAS, produced significantly higher fresh cob yield (180.26 q ha-1) as compared to other weed management approaches (Table 4). Among the different phyto-extract treatments and their application timings, the directed spray of *Parthenium hysterophorus* @ 30% leaf extract at 20 DAS, combined with one inter-cultivation at 40 DAS followed by hand weeding, yielded significantly higher fresh cob yield (159.15 q ha^{-1}) as compared to other phyto-extract treatments. These treatments facilitated minimal crop-weed competition throughout the growth cycle, evident from lower weed dry weight and weed index. Consequently, the crop maximized nutrient, moisture, light, and space utilization, in agreement with findings of Thejasvi [25]. The substantial enhancement in fresh cob yield observed in treatments like inter-cultivation at 20 and 40 DAS followed by one hand weeding, as

Table 1. Total weed density at different growth stages as influenced by different phyto-extracts for weed management in sweet corn under organic production

Treatments	Total weed density (m^{-2})											
	15 DAS			30 DAS			60 DAS			Harvest		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1	6.41^{b*}	6.57^{b}	6.49^{b}	6.41^{e}	6.57^{e}	6.49^{c}	7.87^{bcd}	8.06^{bc}	7.97^{bc}	8.41^{bc}	8.62^{b}	8.51^{bcd}
	(40.64)	(42.63)	(41.63)	(40.65)	(42.68)	(41.67)	(61.45)	(64.52)	(62.99)	(70.23)	(73.74)	(71.99)
T_2	7.72^{a}	7.91^{a}	7.82^{a}	7.63^{b}	7.82^{b}	7.73^{b}	8.17^{b}	8.37^{b}	8.27^{b}	8.84^{b}	9.05^{b}	8.95^{b}
	(59.16)	(62.05)	(60.61)	(57.79)	(60.68)	(59.23)	(66.20)	(69.51)	(67.86)	(77.60)	(81.48)	(79.54)
T_3	7.75^{a}	7.93^{a}	7.84^{a}	7.59^{b}	7.78^{bc}	7.68^{b}	5.23^{f}	5.37^{ef}	5.30^{f}	6.19^{ef}	6.34^{de}	6.26^{f}
	(59.52)	(62.43)	(60.97)	(57.13)	(59.99)	(58.56)	(26.82)	(28.32)	(27.57)	(37.80)	(39.69)	(38.75)
T_4	6.16^{b}	6.31^{b}	6.23^{b}	6.13^{e}	6.27^{e}	6.20^{c}	6.99^{de}	7.16^{cd}	7.08^{d}	7.77^{cd}	7.96^{bc}	7.87^{d}
	(37.43)	(39.26)	(38.35)	(37.06)	(38.91)	(37.99)	(48.37)	(50.79)	(49.58)	(59.93)	(62.93)	(61.43)
T_5	7.67^{a}	7.85^{a}	7.76^{a}	6.51^{e}	6.67^{de}	6.59^{c}	7.22^{cd}	7.39^{bc}	7.30^{cd}	7.95^{bc}	8.15^{bc}	8.05^{cd}
	(58.34)	(61.19)	(59.76)	(41.92)	(44.02)	(42.97)	(51.57)	(54.15)	(52.86)	(62.71)	(65.85)	(64.28)
T_6	7.66^{a}	7.84^{a}	7.75^{a}	6.52^{e}	6.68^{de}	6.60^{c}	4.54^{fg}	4.65^{fg}	4.60^{fgh}	5.41^{fg}	5.54^{ef}	5.47^{fg}
	(58.10)	(60.94)	(59.52)	(42.03)	(44.13)	(43.08)	(20.14)	(21.15)	(20.64)	(28.75)	(30.19)	(29.47)
T_7	6.31^{b}	6.46^{b}	6.39^{b}	6.37^{e}	6.53^{e}	6.45^{c}	7.62^{bcd}	7.81^{bc}	7.72^{bcd}	8.30^{bc}	8.50^{b}	8.40^{bcd}
	(39.35)	(41.28)	(40.31)	(40.14)	(42.15)	(41.14)	(57.64)	(60.52)	(59.08)	(68.35)	(71.77)	(70.06)
T_8	7.78^{a}	7.97^{a}	7.88^{a}	7.49^{bcd}	7.68^{bcd}	7.59^{b}	8.09^{bc}	8.29^{b}	8.19^{b}	8.72^{bc}	8.94^{b}	8.83^{bc}
	(60.08)	(63.02)	(61.55)	(55.65)	(58.43)	(57.04)	(64.97)	(68.22)	(66.59)	(75.58)	(79.36)	(77.47)
T_9	7.72^{a}	7.91^{a}	7.82^{a}	7.44^{bcd}	7.62^{bcd}	7.53^{b}	4.78^{f}	4.89^{f}	4.84^{fg}	5.84^{f}	5.98^{de}	5.91^{fg}
	(59.16)	(62.05)	(60.61)	(54.80)	(57.54)	(56.17)	(22.34)	(23.46)	(22.90)	(33.55)	(35.23)	(34.39)
T_{10}	6.53^{b}	6.68^{b}	6.61^{b}	6.60^{cde}	6.76^{cde}	6.68^{c}	7.99^{bc}	8.19^{bc}	8.09^{b}	8.63^{bc}	8.84^{b}	8.73^{bc}
	(42.12)	(44.18)	(43.15)	(43.07)	(45.22)	(44.15)	(63.42)	(66.59)	(65.01)	(73.91)	(77.61)	(75.76)
T_{11}	7.84^{a}	8.02^{a}	7.93^{a}	7.75^{b}	7.94^{b}	7.84^{b}	8.28^{b}	8.48^{b}	8.38^{b}	8.92^{b}	9.13^{b}	9.02^{b}
	(60.92)	(63.90)	(62.41)	(59.55)	(62.53)	(61.04)	(68.08)	(71.48)	(69.78)	(78.98)	(82.93)	(80.95)
T_{12}	7.80^{a}	7.99^{a}	7.90^{a}	7.50^{bc}	7.69^{bcd}	7.60^{b}	6.20^{e}	6.35^{de}	6.27^{e}	6.93^{de}	7.1^{cd}	7.01^{e}
	(60.38)	(63.33)	(61.86)	(55.80)	(58.59)	(57.20)	(37.90)	(39.80)	(38.85)	(47.52)	(49.90)	(48.71)
T_{13}	7.70^{a}	7.89^{a}	7.80^{a}	3.61^{f}	3.70^{f}	3.65^{d}	3.74^{g}	3.83^{g}	3.79^{h}	4.64^{g}	4.75^{f}	4.70^{h}
	(58.86)	(61.74)	(60.30)	(12.53)	(13.16)	(12.84)	(13.51)	(14.19)	(13.85)	(21.03)	(22.08)	(21.56)
T_{14}	7.92^{a}	8.11^{a}	8.01^{a}	9.49^{a}	9.72^{a}	9.61^{a}	10.67^{a}	10.93^{a}	10.80^{a}	11.82^{a}	12.11^{a}	11.96^{a}
	(62.18)	(65.22)	(63.70)	(89.56)	(94.04)	(91.80)	(113.26)	(118.92)	(116.09)	(139.10)	(146.06)	(142.58)
T_{15}	0.71^{c}	0.71^{c}	0.71^{c}	0.71^{g}	0.71^{g}	0.71^{e}	0.71^{h}	0.71^{h}	0.71^{i}	0.71^{h}	0.71^{g}	0.71^{i}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
S. Em. ±	0.29	0.33	0.24	0.28	0.31	0.22	0.28	0.33	0.22	0.31	0.36	0.24

*Note: * Transformed values ($\sqrt{x+0.5}$), figures in the parentheses indicate original values. Means followed by the same alphabet (s) within a column are not significantly differed by DMRT (P = 0.05); DAS- Days After Sowing*

Table 2. Total dry weight of weeds at different growth stages as influenced by different phyto-extracts for weed management in sweet corn under organic production

Treatments	Total dry weight of weeds (g m^{-2})											
	15 DAS			30 DAS			60 DAS			Harvest		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T_1	4.42^{cde*}	4.51^{cde}	4.46^{b}	7.43^{b}	7.59^{b}	7.51^{bcd}	8.99^{bc}	9.19^{b}	9.09^{bcd}	10.77^{b}	11.00^{b}	10.89^{bc}
	(19.00)	(19.86)	(19.43)	(54.64)	(57.10)	(55.87)	(80.41)	(84.03)	(82.22)	(115.41)	(120.60)	(118.01)
T_2	5.17^{a}	5.28^{ab}	5.22^{a}	8.08^{b}	8.26^{b}	8.17^{bc}	9.52^{bc}	9.73^{b}	9.62^{bc}	11.27^{b}	11.52^{b}	11.39^{bc}
	(26.21)	(27.39)	(26.80)	(64.85)	(67.77)	(66.31)	(90.11)	(94.16)	(92.14)	(126.45)	(132.14)	(129.30)
T_3	5.10^{ab}	5.21^{a-d}	5.15^{a}	8.06^{b}	8.24^{b}	8.15^{bc}	6.22^{d}	6.36^{c}	6.29^{e}	8.33^{c}	8.51^{c}	8.42^{d}
	(25.50)	(26.65)	(26.07)	(64.52)	(67.42)	(65.97)	(38.21)	(39.93)	(39.07)	(68.81)	(71.91)	(70.36)
T_4	4.34^{e}	4.43^{e}	4.39^{b}	7.21^{b}	7.37^{b}	7.29^{d}	8.48^{c}	8.67^{b}	8.57^{d}	10.23^{b}	10.46^{b}	10.35^{c}
	(18.34)	(19.17)	(18.75)	(51.45)	(53.77)	(52.61)	(71.41)	(74.62)	(73.02)	(104.21)	(108.90)	(106.55)
T_5	5.02^{a-d}	5.13^{a-e}	5.08^{a}	7.45^{b}	7.61^{b}	7.53^{bcd}	8.71^{bc}	8.90^{b}	8.8^{cd}	10.48^{b}	10.71^{b}	10.59^{bc}
	(24.75)	(25.86)	(25.31)	(54.96)	(57.43)	(56.20)	(75.31)	(78.70)	(77.00)	(109.29)	(114.21)	(111.75)
T_6	5.04^{abc}	5.15^{a-e}	5.09^{a}	7.43^{b}	7.60^{b}	7.51^{bcd}	5.60^{d}	5.72^{c}	5.66^{e}	7.66^{cd}	7.83^{cd}	7.75^{d}
	(24.86)	(25.98)	(25.42)	(54.75)	(57.21)	(55.98)	(30.85)	(32.24)	(31.54)	(58.21)	(60.83)	(59.52)
T_7	4.39^{de}	4.48^{de}	4.44^{b}	7.32^{b}	7.49^{b}	7.4^{cd}	8.77^{bc}	8.96^{b}	8.87^{cd}	10.58^{b}	10.81^{b}	10.69^{bc}
	(18.75)	(19.59)	(19.17)	(53.14)	(55.53)	(54.34)	(76.41)	(79.85)	(78.13)	(111.36)	(116.37)	(113.87)
T_8	5.13^{a}	5.24^{abc}	5.19^{a}	7.92^{b}	8.09^{b}	8.00^{bcd}	9.27^{bc}	9.47^{b}	9.37^{bcd}	11.11^{b}	11.35^{b}	11.23^{bc}
	(25.84)	(27.00)	(26.42)	(62.15)	(64.95)	(63.55)	(85.37)	(89.21)	(87.29)	(122.85)	(128.38)	(125.61)
T_9	5.06^{abc}	5.17^{a-e}	5.11^{a}	7.86^{b}	8.04^{b}	7.95^{bcd}	5.90^{d}	6.03^{c}	5.96^{e}	8.00^{c}	8.17^{c}	8.09^{d}
	(25.10)	(26.23)	(25.66)	(61.32)	(64.08)	(62.70)	(34.31)	(35.85)	(35.08)	(63.45)	(66.31)	(64.88)
T_{10}	4.47^{b-e}	4.56^{b-e}	4.52^{b}	7.59^{b}	7.76^{b}	7.68^{bcd}	9.17^{bc}	9.37^{b}	9.27^{bcd}	10.92^{b}	11.16^{b}	11.04^{bc}
	(19.45)	(20.33)	(19.89)	(57.18)	(59.75)	(58.47)	(83.51)	(87.27)	(85.39)	(118.81)	(124.16)	(121.48)
T_{11}	5.29^{a}	5.40^{a}	5.34^{a}	8.24^{b}	8.42^{b}	8.33^{b}	9.66^{b}	9.87^{b}	9.76^{b}	11.44^{b}	11.69^{b}	11.56^{b}
	(27.45)	(28.69)	(28.07)	(67.36)	(70.39)	(68.88)	(92.75)	(96.92)	(94.84)	(130.32)	(136.18)	(133.25)
T_{12}	5.16^{a}	5.27^{ab}	5.22^{a}	8.12^{b}	8.30^{b}	8.21^{bc}	6.40^{d}	6.54^{c}	6.47^{e}	8.53^{c}	8.72^{c}	8.62^{d}
	(26.12)	(27.30)	(26.71)	(65.42)	(68.36)	(66.89)	(40.41)	(42.23)	(41.32)	(72.25)	(75.50)	(73.88)
T_{13}	5.17^{a}	5.28^{ab}	5.23^{a}	3.15^{c}	3.22^{c}	3.19^{e}	4.38^{e}	4.47^{d}	4.42^{f}	6.53^{d}	6.67^{d}	6.60^{e}
	(26.24)	(27.42)	(26.83)	(9.45)	(9.88)	(9.66)	(18.66)	(19.50)	(19.08)	(42.12)	(44.02)	(43.07)
T_{14}	5.35^{a}	5.51^{a}	5.43^{a}	10.30^{a}	10.6^{a}	10.45^{a}	12.52^{a}	12.89^{a}	12.71^{a}	13.62^{a}	14.02^{a}	13.82^{a}
	(28.14)	(29.83)	(28.98)	(105.60)	(111.94)	(108.77)	(156.30)	(165.68)	(160.99)	(185.00)	(196.10)	(190.55)
T_{15}	0.71^{f}	0.71^{f}	0.71^{c}	0.71^{d}	0.71^{d}	0.71^{f}	0.71^{f}	0.71^{e}	0.71^{g}	0.71^{e}	0.71^{e}	0.71^{f}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
S.Em. ±	0.19	0.22	0.16	0.30	0.34	0.24	0.33	0.38	0.26	0.40	0.46	0.31

*Note: * Transformed values ($\sqrt{x+0.5}$), figures in the parentheses indicate original values. Means followed by the same alphabet (s) within a column are not significantly differed by DMRT (P = 0.05); DAS-Days After Sowing*

Table 3. Weed control efficiency at different growth stages and weed index as influenced by different phyto-extracts for weed management in sweet corn under organic production

Treatments	Weed control efficiency (%)												Weed index (%)		
	15 DAS			30 DAS			60 DAS			Harvest					
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	pooled
T$_1$	32.48	33.44	32.97	48.26^{cd}	48.99^{cde}	48.62^{cd}	48.55^{def}	49.28^{def}	48.92^{def}	37.62^{efg}	38.5^{d-g}	38.06^{e-h}	36.81^{bcd}	37.47^{bc}	37.14^{cd}
T$_2$	-	-	-	38.59^{f}	39.46^{fg}	39.02^{f}	42.35^{f}	43.16^{ef}	42.76^{fg}	31.65^{gh}	32.62^{fg}	32.13^{hi}	39.05^{bc}	39.68^{bc}	39.37^{bc}
T$_3$	-	-	-	38.90^{ef}	39.77^{fg}	39.33^{f}	75.55^{c}	75.90^{c}	75.73^{c}	62.81^{cd}	63.33^{c}	63.07^{cd}	25.71^{ef}	26.48^{de}	26.10^{f}
T$_4$	34.83	35.75	35.30	51.28^{c}	51.97^{c}	51.62^{c}	54.31^{d}	54.96^{d}	54.64^{d}	43.67^{e}	44.47^{d}	44.07^{e}	33.17^{d}	33.87^{d}	33.52^{e}
T$_5$	-	-	-	47.95^{cd}	48.69^{cde}	48.32^{cd}	51.82^{de}	52.50^{de}	52.16^{de}	40.92^{ef}	41.76^{de}	41.34^{ef}	36.19^{cd}	36.00^{c}	36.10^{de}
T$_6$	-	-	-	48.15^{cd}	48.89^{cde}	48.52^{cd}	80.26^{bc}	80.54^{bc}	80.40^{c}	68.54^{c}	68.98^{c}	68.76^{c}	21.99^{f}	22.81^{f}	22.40^{g}
T$_7$	33.37	34.31	33.85	49.68^{c}	50.39^{cd}	50.03^{c}	51.11^{de}	51.81^{de}	51.46^{de}	39.81^{ef}	40.66^{def}	40.23^{efg}	36.07^{cd}	36.36^{cd}	36.21^{cde}
T$_8$	-	-	-	41.15^{def}	41.98^{efg}	41.56^{ef}	45.38^{ef}	46.15^{def}	45.77^{efg}	33.59^{fgh}	34.53^{efg}	34.06^{ghi}	38.00^{bcd}	38.64^{bc}	38.32^{bc}
T$_9$	-	-	-	41.93^{def}	42.75^{d-g}	42.34^{def}	78.05^{c}	78.36^{c}	78.20^{c}	65.70^{cd}	66.19^{c}	65.95^{cd}	24.91^{ef}	25.69^{ef}	25.30^{fg}
T$_{10}$	30.88	31.86	31.38	45.85^{cde}	46.62^{c-f}	46.24^{cde}	46.57^{def}	47.33^{def}	46.95^{efg}	35.78^{fgh}	36.69^{d-g}	36.23^{f-i}	37.68^{bc}	38.33^{bc}	38.00^{cd}
T$_{11}$	-	-	-	36.21^{f}	37.11^{g}	36.66^{f}	40.66^{f}	41.50^{f}	41.08^{g}	29.56^{h}	30.55^{g}	30.06^{i}	41.12^{b}	41.73^{b}	41.42^{b}
T$_{12}$	-	-	-	38.05^{f}	38.93^{fg}	38.49^{f}	74.15^{c}	74.51^{c}	74.33^{c}	60.95^{d}	61.50^{c}	61.22^{d}	27.44^{e}	28.20^{e}	27.82^{f}
T$_{13}$	-	-	-	91.05^{b}	91.18^{b}	91.11^{b}	88.06^{b}	88.23^{b}	88.15^{b}	77.23^{b}	77.55^{b}	77.39^{b}	11.65^{g}	12.57g	12.11^{h}
T$_{14}$	0.00	0.00	0.00	0.00^{g}	0.00^{h}	0.00^{g}	0.00^{g}	0.00^{g}	0.00^{h}	0.00^{i}	0.00^{h}	0.00^{j}	48.09^{a}	48.63^{a}	48.36^{a}
T$_{15}$	100.00	100.00	100.00	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	0.00^{h}	0.00^{g}	0.00^{i}
S. Em. ±				2.15	2.47	1.90	2.60	2.82	2.22	2.23	2.42	1.95	1.32	1.53	1.03

Note : Means followed by the same alphabet (s) within a column are not significantly differed by DMRT (P = 0.05); DAS- Days After Sowing

Table 4. Fresh cob yield, fresh fodder yield and harvest index as influenced by different phyto-extracts for weed management in sweet corn under organic production

Treatments	Fresh cob yield (q ha ha^{-1})			fresh fodder yield (q ha ha^{-1})			Harvest index (%)		
	2020	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
T_1	132.23^{ef}	125.62^{f}	128.92^{ef}	283.75^{c-f}	266.73^{def}	275.24^{ef}	31.79^{a}	32.02^{a}	31.90^{ab}
T_2	127.54^{fg}	121.16^{fg}	124.35^{ef}	270.47^{fg}	254.24^{fg}	262.36^{ef}	32.04^{a}	32.28^{a}	32.16^{ab}
T_3	155.45^{cd}	147.68^{cd}	151.56^{c}	315.61^{b-e}	296.67^{b-e}	306.14^{cd}	33.00^{a}	33.23^{a}	33.12^{ab}
T_4	139.85^{def}	132.85^{ef}	136.35^{de}	293.41^{c-f}	275.81^{c-f}	284.61^{def}	31.87^{a}	32.10^{a}	31.98^{ab}
T_5	133.52^{ef}	128.56^{de}	131.04^{ef}	291.82^{c-f}	274.31^{c-f}	283.07^{def}	31.94^{a}	32.17^{a}	32.05^{ab}
T_6	163.23^{c}	155.07^{c}	159.15^{c}	324.88^{bc}	305.39^{bc}	315.13^{bc}	33.44^{a}	33.68^{a}	33.56^{ab}
T_7	133.78^{ef}	127.85^{ef}	130.82^{ef}	287.81^{c-f}	270.54^{c-f}	279.18^{def}	32.17^{a}	32.40^{a}	32.28^{ab}
T_8	129.74^{f}	123.25^{f}	126.50^{ef}	275.26^{efg}	258.74^{efg}	267.00^{ef}	32.03^{a}	32.27^{a}	32.15^{ab}
T_9	157.12^{c}	149.26^{cd}	153.19^{c}	317.45^{bcd}	298.4^{bcd}	307.93^{cd}	33.11^{a}	33.34^{a}	33.23^{ab}
T_{10}	130.41^{f}	123.89^{e}	127.15^{ef}	278.21^{d-g}	261.52^{d-g}	269.86^{ef}	31.91^{a}	32.15^{a}	32.03^{ab}
T_{11}	123.21^{fg}	117.05^{fg}	120.13^{fg}	265.63^{fg}	249.69^{fg}	257.66^{fg}	31.69^{a}	31.92^{a}	31.80^{ab}
T_{12}	151.83^{cde}	144.24^{cde}	148.03^{cd}	300.62^{c-f}	282.58^{c-f}	291.6^{cde}	33.56^{a}	33.79^{a}	33.68^{ab}
T_{13}	184.88^{b}	175.64^{b}	180.26^{b}	352.23^{b}	331.10^{b}	341.66^{b}	34.42^{a}	34.66^{a}	34.54^{ab}
T_{14}	108.62^{g}	103.19^{g}	105.90^{g}	237.23^{g}	223.00^{g}	230.11^{g}	31.41^{a}	31.64^{a}	31.52^{b}
T_{15}	209.25^{a}	200.88^{a}	205.07^{a}	392.21^{a}	368.68^{a}	380.44^{a}	34.79^{a}	35.27^{a}	35.03^{a}
S. Em. ±	5.95	5.52	4.55	12.11	11.14	9.07	1.31	1.30	1.00

Note: Means followed by the same alphabet (s) within a column are not significantly differed by DMRT (P = 0.05) DAS- Days After Sowing

Table 5. Economics of sweet corn as influenced by different phyto-extracts for weed management in sweet corn under organic production

Treatments	Gross returns (₹ha^{-1})			Net returns (₹ha^{-1})			B:C ratio		
	2020	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
T_1	239943^{ef}	227662^{ef}	233803^{ef}	161785^{de}	149836^{de}	155811^{de}	3.07^{fgh}	2.93^{efg}	3.00^{ef}
T_2	231111^{fg}	219285^{fg}	225198^{ef}	155179^{de}	143685^{de}	149432^{de}	3.04^{fgh}	2.90^{efg}	2.97^{ef}
T_3	280281^{cd}	265951^{cd}	273116^{c}	201559^{b}	187561^{b}	194560^{bc}	3.56^{bcd}	3.39^{bcd}	3.48^{bc}
T_4	253101^{def}	240141^{def}	246621^{de}	174943^{cd}	162315^{cd}	168629^{d}	3.24^{c-g}	3.09^{c-f}	3.16^{cde}
T_5	242814^{ef}	233127^{ef}	237971^{ef}	166882^{de}	15727^{de}	162205^{d}	3.20^{c-h}	3.08^{c-f}	3.14^{de}
T_6	293656^{c}	278648^{c}	286152^{c}	215252^{b}	200576^{b}	207914^{b}	3.75^{b}	3.57^{b}	3.66^{b}
T_7	242829^{ef}	231614^{ef}	237222^{ef}	164671^{de}	153788^{de}	159230^{de}	3.11^{d-h}	2.98^{d-g}	3.04^{ef}
T_8	235110^{f}	223079^{f}	229095^{ef}	159178^{de}	147479^{de}	153329^{de}	3.10^{e-h}	2.95^{efg}	3.02^{ef}
T_9	283137^{cd}	268663^{cd}	275900^{c}	204415^{b}	190273^{b}	197344^{bc}	3.60^{bc}	3.43^{bc}	3.51^{b}
T_{10}	236477^{f}	224375^{f}	230426^{ef}	158319^{de}	146549^{de}	152434^{de}	3.03^{fgh}	2.88^{efg}	2.95^{ef}
T_{11}	223699^{fg}	212248^{fg}	217974^{fg}	147767^{ef}	136648^{ef}	142208^{e}	2.95^{gh}	2.81^{fg}	2.88^{ef}
T_{12}	272990^{cde}	259040^{cde}	266015^{cd}	194268^{bc}	180650^{bc}	187459^{c}	3.47^{b-f}	3.30^{b-e}	3.39^{bcd}
T_{13}	331031^{b}	314127^{b}	322579^{b}	253335^{a}	236763^{a}	245049^{a}	4.26^{a}	4.06^{a}	4.16^{a}
T_{14}	197515^{g}	187402^{g}	192459^{g}	126035^{f}	116254^{f}	121145^{f}	2.76^{h}	2.63^{g}	2.70^{f}
T_{15}	374021^{a}	358276^{a}	366148^{a}	268197^{a}	255328^{a}	261762^{a}	3.53^{b-e}	3.48^{bc}	3.51^{b}
S. Em. ±	10728	9947	8188	10728	9947	8188	0.13	0.13	0.10

Note: Means followed by the same alphabet (s) within a column are not significantly differed by DMRT (P = 0.05); DAS- Days After Sowing well as the directed application of *Parthenium hysterophorus* at 30% leaf extract at 20 DAS followed by one inter-cultivation at 40 DAS and hand weeding, could be attributed to reduced nutrient uptake by weeds. This was primarily due to effective and regular weed control intervals [29,30]. These outcomes align with the findings of Eranna [24] and Thejasvi [25].

Weed free check recorded significantly higher fresh fodder yield (380.44 q ha^{-1}) than other treatments. The treatments such as inter-cultivation at 20 and 40 DAS followed by one hand weeding recorded higher fresh fodder yield (341.66 q ha^{-1}) among other weed control treatments (Table 4). Directed application of *Parthenium hysterophorus* at 30% leaf extract at 20 DAS and one inter-cultivation at 40 DAS followed by hand weeding recorded comparatively higher the fresh fodder yield (315.13 q ha^{-1}) as compared to other treatments. This could be attributed to lower nutrient uptake by weeds and higher uptake of nutrients by the crop lead to more fodder yield. This was mainly due to effective control of weeds at regular intervals and there was profound increase in yield attributes of sweet corn. These results were similar with the findings of Eranna [24] and Thejasvi [25].

3.3 Economics of different Weed Control Treatments

Gross returns, net returns, and the benefit-cost ratio exhibited significant variations attributed to distinct weed control treatments (Table 5). The weed-free check plot demonstrated notably higher gross returns (Rs. 3,66,148 ha^{-1}). This was due to the superior fresh cob yield, which was a consequence of consistently lower weed density during growth stages and reduced nutrient uptake by weeds. Consequently, the crop benefitted from increased nutrient availability [31,32]. Within the array of weed control approaches, inter-cultivation at 20 and 40 DAS followed by one round of hand weeding yielded the highest gross returns (Rs. 3,22,579 ha^{-1}). In the realm of diverse phyto-extracts and their application timings for sweet corn weed management, a targeted application of *Parthenium hysterophorus* leaf extract at 30% concentration during the 20 DAS stage, combined with a single inter-cultivation at 40 DAS followed by hand weeding (Rs. 2,86,152 ha^{-1}), yielded the most substantial gross returns. These results align with the findings of Eranna [13] and Thejasvi [14]. The same trend was observed for net returns and the benefit-cost ratio. The combination of inter-cultivation at 20 and 40 DAS followed by one hand weeding resulted in higher net returns (Rs. 2,45,049 ha^{-1}) and a B:C ratio of 4.16. These outcomes can be attributed to enhanced economic yield and reduced cultivation costs in the case of sweet corn. Similarly, among the various phyto-extracts and application timings, the directed spray of *Parthenium hysterophorus* leaf extract at 30% concentration during the 20 DAS stage, coupled with inter-cultivation at 40 DAS followed by hand weeding, yielded superior net returns per hectare (Rs. 2,07,914 ha^{-1}) and a B:C ratio of 3.66, compared to other treatments. This was a result of increased fresh cob yield and decreased cultivation costs, aligning with the research findings of Eranna [13] and Thejasvi [14].

4. CONCLUSION

In conclusion, this study delved into diverse weed management approaches for sweet corn, revealing significant impacts on growth and yield. Inter-cultivation at 20 and 40 DAS, paired with selective hand weeding, emerged as a robust strategy, promoting optimal weed control and higher yields. Targeted application of *Parthenium hysterophorus* leaf extract, combined with inter-cultivation and hand weeding, showcased similar efficacy.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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