Short Communication

Allelopathic effect of tulsi (*Ocimum tenuiflorum* L.) on germination and seedling growth of rice, cowpea and upland weeds

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Abstract

Experiments were conducted in the Department of Agronomy, College Agriculture, Vellanikkara to study the allelopathic effects of tulsi (*Ocimum tenuiflorum* L.), on seed germination and seedling growth of rice and cowpea (test crops) and upland weeds. The treatments comprised of aqueous and hot water extracts of shoots and roots of tulsiat 5 g/100 ml and 10 g/100 ml,dry powder of shoots and roots at 10 g/kg soil and 20 g/kg soil and control (distilled water). Tulsi extracts and powders of different parts at all concentrations exhibited phytotoxic activity against test crops and upland weeds. Cowpea was more sensitive than rice. Among weeds, broad leaved weeds showed more inhibition than grass weeds. Treatments which involved dry powder of tulsi (shoots or root) at higher concentration (20 g/kg soil) showed the highest allelopathic activity and can be utilized for the non-selectivecontrol of upland weeds.The present study concluded that tulsiis rich in allelochemicals and exerts allelopathic activity on crops and upland weeds, thus the plant could be considered as an important candidate for the development of plant based natural herbicides in the future.

Key words: Allelopathy, Germination, *Ocimum tenuiflorum*, Seedling growth, Tulsi, Upland weed control.

The interactions between plants has significant positive and negative role in natural ecosystems. Allelopathy is an interference mechanism, in which chemical substances released by one plant inhibit or stimulate the associated plant growth (Rice, 1984). At present, scientists are in search of alternative weed management strategies due to the adverse effect of chemical herbicides on human health and environment. Allelopathy offers great potential for biorational weed control through the production and release of allelochemicals from living or decomposing plant materials (Weston, 1996). Allelopathically active crops can be utilized in different ways as extracts, mulches and residues (Singh et al., 2003), moreover allelochemical based natural herbicides could serve as alternative to synthetic herbicides. Plant derived allelochemicals do not have residual or toxic effects, therefore, they are considered as the perfect substitutes for synthetic herbicides (Cheng and Cheng, 2015).

Tulsi (*Ocimum tenuiflorum* L.) belonging to Lamiaceae family is one of the most important plants in India having a multitude of medicinal properties. Tulsi is rich in secondary metabolites and it has phytotoxic properties (Lawrence, 1998). Besides the therapeutical properties, the phytotoxic activities of tulsi have been less explored. Not only weeds but also cultivated plants are sensitive to allelochemicals. Keeping in view of the allelopathic

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potential of tulsi, the current study was undertaken to investigate the effect of the extracts and powders of tulsi on seed germination and seedling growth of test crops (rice and cowpea) and upland weeds.

The experiment was carried out at College of Agriculture, Kerala Agricultural University, Vellanikkara, during January-March 2021. The experiment was conducted in a completely randomized design (CRD) with 13 treatments and three replications. Treatments were fixed based on method of extraction, concentration and plant part used. Treatments comprised of aqueous and hot water extracts of shoots and roots at 5 g/100 ml and 10 g/ 100 ml, powder of shoots and roots at 10 g/kg soil and 20 g/kg soil and control (distilled water).

Tulsi plants were uprooted from the Agronomy Farm, College of Agriculture, Vellanikkara and washed thoroughly with tap water and separated into root and shoot. The aqueous extracts were prepared by adding two hundred and fifty grams of fresh plant material, were crushed and added to 500 ml of distilled water, and shaken for one hour continuously in an electric shaker. It was kept at room temperature for 48 hr and filtered through Whatman filter paper to obtain stock solution (El-Rokiek and El-Nagdi, 2011). For the preparation of the hot water extract, 500 ml of hot water (70 °C) was added to 250g of crushed tulsi samples and kept for 12 hours and filtered through Whatman filter paper to make the stock solution (Asimiea et al., 2015). From the stock solution, 10 ml and 20 ml were taken and diluted to 100 ml and sprayed. Fresh plant samples of tulsi (shoots or roots) were shade dried for two weeks. The dried shoots and roots of tulsi were powdered separately into fine particles using an electric grinder.

Rectangular plastic trays of dimensions 25 cm × 20 cm × 5 cm were used for the study. The trays were filled with soil and twelve seeds of test crops *i.e*., rice and cowpea were dibbled in trays. Then treatments were imposed and examined daily for germination and growth.

To study effect on upland weeds, soil collected from open area was uniformly filled in plastic trays (25 cm × 20 cm × 5 cm) and then treatments were applied. Weed seedlings germinated from the soil were counted daily and observations on weed density and dry weight recorded one month after application.

Samples of the different extracts and powders used for the study were analyzed for the biochemical parameters, pH, EC, phenols, tannins, alkaloids and flavanoids and are presented in Table 1. ThepH and EC were measured with digital pH meter and conductivity meter respectively. Total phenols, tannins, alkaloids and flavanoids were determined using Folin - Ciocalteu reagent, Folin-Denis reagent, 10 per cent acetic acid in ethanol and aluminium chloride respectively (Harborne, 1973).

Observations on test crops such as mean germination time (MGT), speed of germination (S) and final germination percentage (GP) were estimated using standard methods. Mean germination time and speed of germination were calculated as per the formula of Basra et al. (2005) and Allan et al. (1962) respectively. The formulae

Table 1. Biochemical properties of tulsi extracts and powders

Extracts and powder	pH	EC (dS/m)	Phenols (mg/100ml or 100 g)	Tannins (mg/100ml or 100 g)	Alkaloids (mg/100ml or 100 g)	Flavanoids (mg/100ml or 100 g)
Aqueous extract - Shoot	6.16	0.220	4.79	0.45	166.67	41.76
Aqueous extract - Root	5.85	0.015	4.16	0.54	406.63	25.90
Hot water extract - Shoot	5.97	0.240	4.53	0.49	126.67	33.72
Hot water extract - Root	5.76	0.018	4.05	0.59	266.67	22.99
Powder -Shoot	5.67	0.230	4.95	0.46	556.67	37.70
Powder - Root	5.56	0.210	4.39	0.65	813.20	24.25

are as follows:

Mean germination time : MGT $= \Sigma (n \times d) / N$

Where n = number of seeds germinated on each day, d = number of days from the beginning of the test, and N = total number of seeds germinated at the termination of the experiment.

Speed of germination: $S = N_1 / T_1 + N_2 / T_2 + N_3 / T_3 + \ldots\ldots\ldots + N_k / T_k$;

Where, N_1, N_2, N_3, ..., N_k are the number of seeds germinated at T_1, T_2, T_3, ..., T_k days after sowing

Germination percentage: (GP):

$$\frac{\text{Seeds germinated at the end of trial}}{\text{Number of initial seeds used}}$$

Shoot length, root length, fresh weight and dry weight of test crops were recordedat one month after application. Weeds germinated after treatment application was counted at weekly intervals. Density and dry weight of weeds were measured at one month after application and mean values were recorded.

The data generated from the experiment was analyzed using analysis of variance (ANOVA) with statistical package 'WASP 2' (Statistical package, ICAR Goa).

Effect of tulsi on test crops (rice and cowpea)

Germination indices and seedling growth of rice were affected by the application of extracts and powders of tulsi (Table 2). Speed of germination was significantly lower in treatments that involved tulsishoot and root powder at 20 g/kg soil (2.49 and 2.56 nos./day) and it was on par with shoot and root powder of tulsi at 10 g/kg soil (2.72 and 2.77 nos./ day). Also, the presence of tulsi extracts and powders in soil significantly enhanced the mean germination time. Application of tulsi shoot and root powder at 20 g/kg soil and powder of shoot and root at 10 g/kg soil recorded higher mean germination time, *i.e*., 4.55, 4.31, 4.3, 4.23 days respectively. Incorporation of powdered form of shoot and root of tulsi at 10 and 20g/kg soil significantly delayed germination of rice. Final germination percentage of rice was significantly lower in treatment with shoot powder at 20 g/kg soil (86.10 %) and it was on par with root powder at 20 g/kg soil (88.90 %), shoot and root powder at 10 g/kg soil (94.47 %) and aqueous extract of shoot at 10 g/100ml (94.47 %). The powdered form of

Table 2. Effect of tulsi extracts and powders on germination and seedling growth of rice

Treatments	Speed of germination (nos. /day)	Mean germination (days)	Final germination (%)	Shoot length (cm) at 30 DAP	Root length (cm) at 30 DAP	Fresh weight (g/m^2) at 30 DAP	Dry weight (g/m^2) at 30 DAP
T_1 - Aqueous extract of shoot(5 g/100 ml)	3.30^{ab}	3.81^{c}	100.00^{a}	29.83^{bcde}	7.70	303.33^{abcd}	60.67^{ab}
T_2 - Aqueous extract of shoot (10 g/100 ml)	3.00^{cd}	3.91^{bc}	94.47^{abc}	28.50^{def}	7.60	270.00^{de}	51.33^{c}
T_3 - Aqueous extract of root (5 g/100 ml)	3.31^{ab}	3.78^{c}	100.00^{a}	30.17^{bcde}	7.73	315.33^{abc}	60.00^{ab}
T_4 - Aqueous extract of root (10 g/100 ml)	3.19^{bc}	3.80^{c}	97.23^{ab}	29.27^{cdef}	7.67	280.00^{cde}	53.33^{bc}
T_5 - Hot water extract of shoot(5 g/100 ml)	3.34^{ab}	3.75^{c}	100.00^{a}	32.67^{abc}	8.20	323.33^{ab}	63.33^{a}
T_6 - Hot water extract of shoot (10 g/100 ml)	3.29^{ab}	3.81^{c}	100.00^{a}	31.60^{abcd}	8.00	320.00^{ab}	61.33^{a}
T_7 - Hot water extract of root (5 g/100 ml)	3.34^{ab}	3.75^{c}	100.00^{a}	33.17^{ab}	8.13	326.67^{ab}	64.67^{a}
T_8 - Hot water extract of root (10 g/100 ml)	3.29^{ab}	3.81^{c}	100.00^{a}	32.17^{abc}	8.00	318.00^{ab}	62.00^{a}
T_9 - Powder (shoot 10 g/kg soil)	2.72^{de}	4.30^{ab}	94.47^{abc}	27.77^{efg}	7.33	300.00^{abcd}	59.33^{ab}
T_{10} - Powder (shoot 20 g/kg soil)	2.49^{e}	4.55^{a}	86.10^{c}	25.67^{fg}	7.00	256.67^{e}	48.67^{c}
T_{11} - Powder (root 10 g/kg soil)	2.77^{de}	4.23^{ab}	94.47^{abc}	28.33^{def}	7.50	290.00^{bcde}	60.00^{ab}
T_{12} - Powder (root 20 g/kg soil)	2.56^{e}	4.31^{a}	88.90^{bc}	24.17^{g}	7.03	260.00^{e}	50.00^{c}
T_{13} - Control	3.47^{a}	3.58^{c}	100.00^{a}	34.77^{a}	8.23	330.00^{a}	66.67^{a}
SEm (±)	0.093	0.081	1.302	0.841	0.114	7.161	1.612
CD (0.05)	0.284	0.385	8.577	3.615	NS	36.869	7.791

shoot and root at 20 g/kg soil inhibited germination of rice by 13.9 and 11.1 per cent, respectively.

Shoot length of rice was significantly lower in all treatments except hot water extracts of shoot and root of tulsi. Among different treatments, incorporation of tulsi root powder at 20 g/kg soil had significantly lower shoot length (24.17 cm) and was on par with shoot powder at 20 g/kgsoil (25.67 cm) and 10 g/kg soil (27.77 cm). Root length was not significantly influenced by treatments. Significantly lower fresh weight of rice was recorded in tulsi shoot powder at 20 g/kg soil (256.67 g/m^2) and it was on par with root powder at 10 and 20 g/kg soil and aqueous extract of shoot and root at 10 g/100ml. Application of tulsi shoot and root powder at 20 g/kg soil and aqueous extract of shoot and root at 10 g/100 ml significantly reduced dry weight of rice at one month after application.

Application of powdered form of tulsi shoot and root at 10 and 20g/kg soil has significant allelopathic effect on rice germination and seedling growth. Verma et al. (2012) reported inhibitory effect of tulsi on germination, root and shoot elongation of important cereal crops; maize, wheat and barley. According to them, allelopathic effect was exhibited by all tested extracts of tulsi with maximum in leaf followed by root and seed extract. In the present study maximum inhibition was showed by powder followed by aqueous extract and hot water extract. Dafaallah and Ahmed (2019) also screened phytotoxic activity of sweet basil on cereal crops and reported that aqueous extract of aboveground parts of sweet basil inhibited seed germination of sorghum, millet, maize and wheat. Tulsi plants contain various biologically active compounds that might have contributed to its phytotoxic effect (Nahak et al., 2011).

Allelopathic effect of different extracts and powders of tulsi on germination and seedling growth of the test crop cowpea are given in Table 3. Speed of germination was the highest in control (4.86 nos./day) and it was reduced significantly in all treatments with tulsi. Application of tulsi shoot powder at 20 g/kg soil recorded the lower speed of germination (1.87nos./day) and was statistically at par with root powder at 20 g/kg soil (1.99nos./day). Similarly mean germination time, an indicator of length of lag period to germination, was significantly higher in shoot and root powder at 20 g/kg soil (5.34 and 5.24 days) and it was on par

Table 3. Effect of tulsi extracts and powders on germination and seedling growth of cowpea

Treatments	Speed of germination (nos. /day)	Mean germination (days)	Final germination (%)	Shoot length (cm) at 30 DAP	Root length (cm) at 30 DAP	Fresh weight (g/m^2) at 30 DAP	Dry weight (g/m^2) at 30 DAP
T_1 - Aqueous extract of shoot (5 g/100 ml)	3.88^{de}	3.15^{de}	94.47^{ab}	18.17^{bc}	6.50^{de}	1023.33^{bcd}	112.00^{bc}
T_2 - Aqueous extract of shoot (10 g/100 ml)	3.34^{f}	3.61^{c}	91.70^{abc}	16.67^{cde}	5.33^{fg}	976.67^{cde}	105.93^{bcd}
T_3 - Aqueous extract of root (5 g/100 ml)	3.86^{de}	3.28^{cde}	97.23^{ab}	18.50^{abc}	7.00^{cd}	1033.33^{bc}	113.00^{bc}
T_4 - Aqueous extract of root (10 g/100 ml)	3.56^{ef}	3.44^{cd}	94.43^{ab}	17.33^{bcd}	6.00^{ef}	980.00^{cde}	108.00^{bcd}
T_5 - Hot water extract of shoot (5 g/100 ml)	4.37^{bc}	3.06^{def}	100.00^{a}	18.33^{abc}	8.00^{ab}	1113.33^{ab}	117.80^{b}
T_6 - Hot water extract of shoot (10 g/100 ml)	4.14^{cd}	3.22^{cde}	100.00^{a}	17.50^{bcd}	7.33^{bcd}	1100.00^{b}	108.60^{bcd}
T_7- Hot water extract of root (5 g/100 ml)	4.51^{b}	2.89^{ef}	100.00^{a}	19.00^{ab}	8.33^{a}	1126.67^{ab}	119.00^{b}
T_8 - Hot water extract of root (10 g/100 ml)	4.28^{bc}	3.08^{def}	100.00^{a}	18.83^{abc}	7.67^{abc}	1106.67^{ab}	114.00^{bc}
T_9 - Powder (shoot 10 g/kg soil)	2.26^{h}	4.97^{ab}	88.87^{bcd}	14.50^{ef}	4.83^{gh}	920.00^{def}	100.67^{cd}
T_{10} - Powder (shoot 20 g/kg soil)	1.87^{i}	5.34^{a}	80.53^{d}	11.00^{g}	3.83^{i}	860.00^{f}	96.67^{d}
T_{11} - Powder (root 10 g/kg soil)	2.74^{g}	4.58^{b}	91.70^{abc}	15.83^{de}	4.17^{hi}	966.67^{cdef}	102.00^{cd}
T_{12} - Powder (root 20 g/kg soil)	1.99^{hi}	5.24^{a}	83.33^{cd}	13.17^{fg}	3.67^{i}	886.67^{ef}	99.80^{cd}
T_{13} - Control	4.86^{a}	2.67^{f}	100.00^{a}	20.50^{a}	8.50^{a}	1212.00^{a}	134.33^{a}
SEm (±)	0.277	0.262	1.831	0.732	0.480	28.933	2.794
CD (0.05)	0.322	0.419	8.388	2.308	0.861	111.040	14.645

with shoot powder at 10 g/kg soil (4.97 days). The final germination percentage was significantly lower in treatment which received tulsi shoot powder at 20 g/kg soil (80.53 %) andit was on par with root powder at 20 g/kg soil (83.33 %) and shoot powder at 10 g/kg soil (88.87 %). The powder form of shoot and root at 20 g/kg soil inhibited germination percentage of cowpea by 19.47 per cent and 16.67 per cent respectively.

The shoot and root length of cowpea seedlings were also affected by the application of extracts and powders of tulsi. Compared to control, shoot length of cowpea was reduced by 46.34 and 35.76 per cent respectively due to the application of tulsi shoot powder and root powder at 20 g/kg soil. Root length was lower in tulsi root powder at 20 g/kg soil (3.67 cm) and was statistically on par with shoot powder at 20 g/kg soil (3.83 cm) and root powder at 10 g/kg soil (4.17 cm). Control recorded higher shoot length and root length (20.5 and 8.5 cm). Fresh weight of cowpea was significantly lower in tulsi shoot powder at 20 g/kg soil (860 g/m^2) and it was on par with tulsi root powder at 20 g/kg soil (886.67 g/m^2) and shoot and root powder at 10 g/kg soil (920 and 966.67 g/m^2). Dry weight of cowpea was significantly lower in tulsi shoot powder at 20 g/kg soil (96.67 g/m^2) and it was on par with root powder at 20 g/kg soil (99.8 g/m^2), shoot and root powder at 10 g/kg soil (100.67 and 102.00 g/m^2), aqueous extract of shoot and root at 10 g/100 ml (105.93 and 108.00 g/m^2), and hot water extract of shoot at 10 g/100 ml (108.60 g/m^2). Control recorded maximum fresh weight and dry weight (1212 and 134.33 g/m^2 respectively).

Germination and seedling growth of cowpea were affected by tulsi extracts and powders and the inhibitory effect was the highest with powder form, followed by aqueous extracts. Hot water extracts exhibited the lowest effect. Suwitchayanon et al. (2017) evaluated phytotoxic activity of fourteen medicinal plants on test crop lettuce and reported that *Ocimum tenuiflorum* inhibited lettuce radical and hypocotyl growth by 74.0 per cent and 31.8 per cent respectively. The inhibitory activity of *O. tenuiflorum* plant extracts on the germination and seedling growth of other plant species was also reported by Islam and Kato-Noguchi (2014).

It was observed from the study that cowpea was more sensitive than rice. Plants responded to various *Ocimum* extracts through morphological, anatomical and physiological adjustments and this vary from one species to another (Mekky et al., 2019) and this might be the reason for differential response of test crops rice and cowpea in this study.

Effect of tuls ion upland weeds

Major weeds germinated from trays were *Trianthema portulacastrum*, *Alternanthera philoxeroides*, *Boerhavia diffusa*, *Cleome viscosa, Euphorbia hirta*, *Amaranthus spinosus* and *Panicum repens*. All extracts and powders of tulsi had significant effects on germination count of weeds at 1st week (Table 4). Control recorded the highest germination of weeds (166.67 nos./m^2) at first week and was significantly superior to all other treatments. The lowest germination count was observed in treatments which received tulsi shoot powder at 20 g/kg soil (3.33nos./m^2) and tulsi root powder at 20 g/kg soil (6.67nos./m^2). Application of shoot and root powders of tulsi at 20 g/kg soil caused weed germination inhibition of 86.06 per cent and 79.56 per cent, respectively in the first week. Application of extracts and powder irrespective of concentration, method of extraction and plant part used, delayed germination of upland weeds.

Data on the effect of treatments on weed density and weed dry weight after one month are presented in Table 5. Density of broad leaved weeds was significantly lower in tulsi shoot and root powder at 20 g/kg soil (140.33 and 144.33 nos./m^2), followed by root and shoot powder at 10 g/kg soil (180.00 and 190.33 nos./m^2). Total weed density was significantly lower in tulsi shoot and root

Table 4. Effect of tulsi extracts and powders on weed germination at weekly intervals

Treatments	Germination count (nos./m^2)			
	1st week	2nd week	3rd week	4th week
T_1 - Aqueous extract of shoot (5 g/100 ml)	8.59^{c}(73.33)	13.40(180.00)	7.30(53.33)	4.14(16.67)
T_2 - Aqueous extract of shoot (10 g/100 ml)	7.76^{c}(60.00)	13.42(180.00)	6.82(46.67)	4.02(15.67)
T_3 - Aqueous extract of root (5 g/100 ml)	8.59^{c}(73.33)	13.42(180.00)	6.57(43.33)	4.18(17.00)
T_4 - Aqueous extract of root (10 g/100 ml)	8.19^{c}(66.67)	13.16(173.33)	6.57(43.33)	4.22(17.33)
T_5 - Hot water extract of shoot (5 g/100 ml)	10.33^{b}(106.67)	12.38(153.33)	7.07(50.00)	4.22(17.33)
T_6 - Hot water extract of shoot (10 g/100 ml)	9.68^{b}(93.33)	11.81(140.00)	7.41(55.00)	4.14(16.67)
T_7 - Hot water extract of root (5 g/100 ml)	10.67^{b}(113.33)	12.38(153.33)	6.80(46.67)	4.22(17.33)
T_8 - Hot water extract of root (10 g/100 ml)	10.33^{b}(106.67)	12.28(153.33)	6.82(46.67)	4.13(16.67)
T_9 - Powder (shoot 10 g/kg soil)	4.43^{d}(20.00)	12.91(166.67)	7.63(58.33)	3.93(15.00)
T_{10} - Powder (shoot 20 g/kg soil)	1.80^{e}(3.33)	11.49(133.33)	7.51(56.67)	3.97(15.33)
T_{11} - Powder (root 10 g/kg soil)	5.19^{d}(26.67)	12.10(146.67)	7.63(58.33)	4.14(16.67)
T_{12} - Powder (root 20 g/kg soil)	2.64^{e}(6.67)	11.78(140.00)	7.07(50.00)	3.89(14.67)
T_{13} - Control	12.92^{a}(166.67)	11.54(133.33)	6.70(45.00)	3.79(14.00)
SEm (±)	0.923	0.200	0.1008	0.039
CD (0.05)	1.062	NS	NS	NS

powder at 20 g/kg soil (208.67 and 211.33 nos./m^2) and it was on par with root and shoot powder of tulsi at 10 g/kg soil (248.33 and 260.00 nos./m^2). Dry weight of broad leaved weeds and total weeds were significantly lower in tulsi shoot powder at 20 g/kg soil (17.47 and 21.33 g/m^2) and it was on par with root powder at 20 g/kg soil (19.43 and 23.33 g/m^2), shoot powder at 10 g/kg soil (21.03 and 25.00 g/m^2) and root powder at 10 g/kg soil (23.33 and 27.33 g/m^2). There was no significant difference in density as well as dry weight of grass weeds. Among weeds, broad leaved weeds showed more inhibition than grass weeds.Among the treatments, powder of shoot and root of tulsi at 20 g/kg soil exhibited the highest allelopathic activity against weeds. The powder form of shoot and root at 20 g/kg soil decreased total weed density by 41.87 and 41.13 per cent and total weed dry weight by 53.63 and 49.2 per cent respectively. Sharma and Singh (2003), observed complete inhibition of germination of all tested weed species with the addition of 7.5 g basil leaf powder to 100 g of sand. They also found that 10 % (w/v) basil leaf extract significantly inhibited germination of redroot pigweed and hairy beggarticks. Spraying of *Ocimum basilicum* leaf extracts up to 25 per cent inhibited

Table 5. Effect of tulsi extracts and powders on weed density and weed dry weight at one month after application

Treatments	Weed density (nos./m^2)			Weed dry weight (g/m^2)		
	Grasses	Broad leaved	Total weeds	Grasses	Broad leaved	Total weeds
T_1 - Aqueous extract of shoot (5 g/100 ml)	8.35(70.00)	15.89^{ab}(253.33)	17.97^{a}(323.33)	2.02(4.10)	5.61^{abc}(31.57)	5.96^{bc}(35.67)
T_2 - Aqueous extract of shoot (10 g/100 ml)	8.19(67.33)	15.33^{b}(235.00)	17.36^{abc}(302.33)	1.98(3.93)	5.17^{bcd}(26.73)	5.54^{cd}(30.67)
T_3 - Aqueous extract of root (5 g/100 ml)	8.31(70.00)	15.60^{ab}(243.67)	17.71^{ab}(313.67)	2.05(4.23)	5.92^{ab}(35.10)	6.27^{ab}(39.33)
T_4 - Aqueous extract of root (10 g/100 ml)	8.30(69.00)	15.21^{b}(231.67)	17.33^{abc}(300.67)	2.00(4.00)	5.83^{ab}(34.00)	6.16^{abc}(38.00)
T_5 - Hot water extract of shoot (5 g/100 ml)	8.43(71.33)	15.99^{ab}(256.00)	18.06^{a}(327.33)	2.05(4.20)	6.09^{a}(37.13)	6.42^{ab}(41.33)
T_6 - Hot water extract of shoot(10 g/100 ml)	8.23(67.67)	15.40^{b}(237.33)	17.46^{abc}(305.00)	2.02(4.10)	5.82^{ab}(33.90)	6.16^{abc}(38.00)
T_7 - Hot water extract of root (5 g/100 ml)	8.54(73.00)	16.05^{ab}(257.67)	18.17^{a}(330.67)	2.00(4.03)	6.16^{a}(37.97)	6.48^{ab}(42.00)
T_8 - Hot water extract of root (10 g/100 ml)	8.52(72.67)	15.82^{ab}(250.67)	17.97^{a}(323.33)	1.99(4.00)	5.97^{a}(35.67)	6.29^{ab}(39.67)
T_9 - Powder (shoot 10 g/kg soil)	8.34(69.67)	13.79^{c}(190.33)	16.10^{bcd}(260.00)	1.99(3.97)	4.58^{de}(21.03)	5.00^{de}(25.00)
T_{10} - Powder (shoot 20 g/kg soil)	8.26(68.33)	11.83^{d}(140.33)	14.41^{d}(208.67)	1.97(3.87)	4.17^{e}(17.47)	4.61^{e}(21.33)
T_{11} - Powder (root 10 g/kg soil)	8.26(68.33)	13.39^{c}(180.00)	15.68^{cd}(248.33)	1.99(4.00)	4.82^{cde}(23.33)	5.23^{de}(27.33)
T_{12} - Powder (root 20 g/kg soil)	8.18(67.00)	11.96^{d}(144.33)	14.50^{d}(211.33)	1.97(3.90)	4.40^{de}(19.43)	4.82^{de}(23.33)
T_{13} - Control	8.66(75.00)	16.85^{a}(284.00)	18.92^{a}(359.00)	2.09(4.37)	6.37^{a}(41.63)	6.71^{a}(46.00)
SEm (±)	0.041	0.444	0.396	0.009	0.204	0.193
CD (0.05)	NS	1.310	1.833	NS	0.787	0.855

growth of grass weed (*Phalaris minor*) and broad leaf weed (*Anagalis arvensis*) (El-Rokiek et al., 2018). Fanaei et al. (2013) reported that chlorophyll content of weeds such as *Abutilon* and *Centaury* decreased on using extracts of different concentrations of tulsi.

Tulsi extracts and powders of different parts at all concentrations exhibited phytotoxic activity against test crops (rice and cowpea) and upland weeds. The observed reduction in seed germination and seedling growth could be due to allelopathic phytochemicals such as alkaloids, flavanoids, phenols and tannins that were present in the extracts and powders (Table 1). To determine the extent of allelopathic contribution of each one of these compounds, correlation was worked out between content of allelochemicals in extracts and powders and germination and seedling growth of test crops and upland weeds (Table 6). Total alkaloids showed significant negative correlation with speed of germination (-0.880*, -0.802*), germination percentage (-0.858*, -0.702), shoot length (-0.841*, -0.676*), root length (-0.879*, -0.796*), fresh weight (-0.694*, -0.731*) and dry weight (-0.631*, -0.716*) of rice and cowpea, respectively. Total phenols, tannins and flavanoids also showed negative relationship with germination and seedling growth of test crops, while correlation was non significant. Regarding upland weeds, total alkaloids expressed strong negative correlation with germination count at first week (-0.815*), dry weight of broad leaved weeds (-0.734*) and total weeds (-0.733*). Total phenols in tulsi extracts and powders also exhibited significant negative correlation with weed germination count, dry weight of broad leaved weeds and total weeds (-0.539*, -0.634* and -0.631* respectively). In addition, total alkaloids showed, significant negative correlation with density of broad leaved weeds (-0.844*) and total weeds (-0.838*). Phytotoxic effects of *Ocimum* might be due to different allelochemicals present in the extracts and powders and it is interpreted that the total alkaloids contributed maximum to the phytotoxicity.

Allelochemicals influences the cell division, cell elongation, membrane permeability and enzyme activity of receiver plants (Dragoeva et al., 2015). The growth reduction induced by allelochemicals might be either due to the prevention of cell division and enlargement or by the inhibition of IAA and GA_3 (Tomaszewski and Thimann, 1966). In allelochemicals, alkaloid fraction causes oxidative stress that generates reactive oxygen species thereby initiates metabolic derangement in plants (Ogunsusi

Table 6. Content of allelochemicals in extracts and powders and germination and seedling growth of test crops and upland weeds

	Test crop-rice				Test crop-cowpea			
	Total phenols	Total tannins	Total alkaloids	Total flavanoids	Total phenols	Total tannins	Total alkaloids	Total flavanoids
SG	-0.382	-0.314	-0.880*	0.012	-0.543	-0.048	-0.802*	-0.177
G%	-0.219	-0.458	-0.858*	-0.132	-0.569	0.031	-0.702*	-0.256
Shoot length	-0.330	-0.293	-0.841*	-0.015	-0.589	0.050	-0.676*	-0.238
Root length	-0.310	-0.321	-0.879*	-0.022	-0.509	-0.098	-0.796*	-0.178
Fresh weight	-0.227	-0.301	-0.694*	-0.003	-0.547	0.045	-0.731*	-0.247
Dry weight	-0.070	-0.379	-0.631*	-0.107	-0.570	0.017	-0.716*	-0.238

	Upland weeds			
	Total phenols	Total tannins	Total alkaloids	Total flavanoids
GC-1st week	-0.539*	-0.052	-0.815*	-0.186
Density-grass	-0.482	0.100	-0.398	-0.328
Density- BLW	-0.403	-0.218	-0.844*	-0.004
Density-total weeds	-0.414	-0.207	-0.838*	-0.018
Dry weight-grass	-0.311	-0.120	-0.504	-0.075
Dry weight-BLW	-0.634*	0.007	-0.734*	-0.282
Dry weight-total weeds	-0.631*	0.005	-0.733*	-0.280

et al., 2018). Treatments that received powder of tulsi (shoot or root) showed the highest allelopathic effect on crops and weeds, followed by aqueous extract and hot water extract. Higher allelopathic activity of tulsi powder might be due to the gradual release of allelochemicals after decay (Chou and Patrick, 1976).

From the study it can be concluded that tulsi (*Ocimum tenuiflorum* L.) is rich in allelochemicals and exerts allelopathic activity on crops and upland weeds. Thus, the plant could be considered as an important candidate for the development of plant based natural herbicides in the future.

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