Indian J. Weed Sci. **41** (1 & 2) : 12-22 (2009)

Interactions of Basil (*Ocimum sanctum* L.) with Some Weed Species–Competition or Allelopathy?

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ABSTRACT

Effect of basil leachate on the emergence of 10 weed species, beggarweed (*Desmodium tortuosum*), crabgrass (*Digitaria ciliaris*), guineagrass (*Panicum maximum*), Johnsongrass (*Sorghum halepense*), milkweed strangler vine (*Morrenia odorata*), pigweed (*Amaranthus retroflexus*), sicklepod (*Senna obtusifolia*), Spanish needles (*Bidens pilosa*), teaweed or prickly sida (*Sida spinosa*) and yellow nutsedge (*Cyperus esculentus*) alongwith basil (*Ocimum sanctum*) was studied in Petridish and under pot conditions. In another study, intra- and inter-specific competition between basil and 10 weed species (guineagrass) substituted with crowfoot grass (*Dactyloctenium aegyptium*) was carried out in pots under greenhouse conditions in a replacement series with four plants per pot. Effect of weed : basil mixture on fresh weight and plant height was observed. Relative crowding coefficients (RCC), relative yield total (RYT) and agressivity index (AI) was calculated. Basil leachate collected from soil influenced weed emergence (both inhibitory and stimulatory), but the differences between leachate or water used for irrigation in pots and Petri dish studies were not large enough except on some species, indicating any significant role of allelochemicals. Basil leachate inhibited the emergence of basil itself. Similarly, soil incorporation of basil root/shoot matter in 1 : 12 ratio (basil : soil) had no inhibitory effect on the emergence of *D. tortuosum, S. halepense, M. odorata, A. retroflexus, S. obtusifolia, B. pilosa* and *C. esculentus*. Basil suppressed the growth of all weed species, except yellow nutsedge, but plant height of basil was unaffected by weeds (when data averaged over weed species and plant ratio). Plant height of basil increased when growing with weed species compared to monoculture due to inter-specific competition. Even single plant of basil (with three of weeds) was competitive enough to reduce the plant height of *D. aegyptium, S. spinosa, A. retroflexus* and *M. odorata;* plant height increased significantly when weeds were growing in monoculture. RYT values of 1.04 in 1 : 3 mixture of basil with weeds compared to 0.83 in 3 : 1 or 2 : 2 ratio indicated some degree of resource complimentarity. Highest RYT value of 1.64 was derived for *D. aegyptium* followed by *D. tortuosum* (1.22), *S. spinosa* (1.14) and *C. esculentus* (1.06) when growing in 1 : 3 ratio with basil. RCC (basil on weeds and weeds on basil) values were significantly different for *C. esculentus* compared to other weed species when growing in 2 : 2 ratio. The aggressivity index of basil significantly decreased when one plant of basil was growing with three of weed species compared to 2 : 2 or 3 : 1 ratio (basil : weeds); lowest being with *C. esculentus*. The results suggest that insignificant effect on weed seed emergence with basil leachate may not be due to any allelopathic effect as the growth inhibition (plant height and fresh weight) does not support this hypothesis, but suggests dominant role of competition when weeds and basil were growing in different plant ratio.

Key words : Basil leachate, weed emergence, fresh weight, plant height, weed competition

INTRODUCTION

The allelopathy phenomenon where a plant species chemically interferes with the germination, growth or development of other plant species has been known for over 2000 years. Early reference of 300 BC suggests this phenomenon where many crop plants viz., gram (*Cicer arietinum*) and barley (*Hordeum vulgare*) inhibited growth of some weeds and crop plants other than barley (Rice, 1984). Allelochemicals can be present in most parts of plants viz. roots, rhizomes, leaves, stems, pollen, seeds and flowers and released into the environment by root exudation, leaching from aboveground parts, volatilization and plant decomposition material. Like herbicides have no common mode of action or physiological target site for all allelochemicals, but when susceptible plants are exposed to allelochemicals, germination, growth and development may be affected. Reduced seed germination, coleoptiles and radical elongation and root/shoot growth inhibition are the most common allelopathic symptoms (Rice, 1984). Allelochemicals can also inhibit cell division, pollen germination, nutrient uptake, photosynthesis, and specific enzyme functions in sensitive plants.

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Allelopathic interactions between plants have been studied both under cultivated and natural ecosystems. In agricultural systems, allelopathy can be part of the interference between crops and between crops and weeds and may therefore affect the economical outcome of plant production. Both crop and weed species with allelopathic activity are known (Putnam and Tang, 1986; Inderjit *et al*., 1999; Reigosa *et al*., 2006). The development of weed management strategies that make use of allelopathic crop plants is receiving increased national and international attention. It has recently been said that no area of plant science has provoked as much controversy as the study of allelopathy (Romeo and Weidenhamer, 1998). Allelopathic crop plants can be used to control weeds by competition/smothering weeds in field or horticultural crops or in a rotational sequence, its residue or mulch inhibiting weed emergence and subsequently their growth. Alternatively, application of allelopathic compounds extracted from potential allelopathic plants or synthesized can be used alone or synergistically with fertilizers or pesticides (herbicides) to improve crop plants' growth and suppress weeds.

Basil or Holy basil, *Ocimum sanctum* L., Syn. *O. tenuiflorum* belongs to Lamiaceae (Mint) family and is a tropical plant of 0.5-1.5 m tall, much branched, annual in growth habit and its leaves contain essential (volatile) oil, euganol, eugenal, carvacerol, methyl-chavicol, limatrol and caryophylline, etc. Basil seed oil contains fatty acids and sitosterol and has been used as a herbal or in ayurvedic medicines. Its insecticidal properties against mosquitoes and other insects are well known; it also possesses anti-microbial, anti-inflammatory (eugenol oil), anti-allergic (urosolic acid), anti-stress (eugenol and methyl-eugenol), anti-hypertensive, CNS depressant and anti-fungal properties (Devi and Ganasoundari, 1999; Puri, 2002; Sethi *et al.*, 2002; Praksah and Gupta, 2005; Biswas and Biswas, 2005). Basil acts as a powerful antioxidant, scavanging free radicals, improving immune system and has been found effective against colds, cough, sore throat, respiratory disorders and flu and has even been advised for swine flu (H1N1). Nematocidal properties from basil oil have also been reported (Sangwan *et al.,* 1990). Also, basil leaf extract was found to contain banana disease development (Singh *et al.,* 1993).

Chouliaras *et al.* (2007) reported that soil incorporation of basil plant tissues (1 : 12.5 ratio) increased mineralization and availability of macro- and micro-nutrients and decreased soil bacterial colonies. Sharma and Singh (2003) reported allelopathic effect of basil on some weed species; however, there is paucity of literature on the allelopathic effect of basil on weeds. Keeping this in view, a series of laboratory and greenhouse studies were carried out to confirm the allelopathic effect of basil on weeds emergence and growth.

MATERIALS AND METHODS

Effect of Basil Leachate on Weed Seed Germination

Seed collected from basil plants growing in the greenhouse of University of Florida, Citrus Research and Education Center, Lake Alfred, USA were raised in sandy loam soil in Styrofoam pots at 25^{O}C temperature and 70% RH. Thinning was done a week after emergence and one plant per pot was maintained. After 60 days, when plants were at flowering stage, leachate was collected by placing basil pot in another Styrofoam pot. There were 30 plant pots for collecting leachate. Basil plants were watered in the evening; leachate was collected in the morning and used for germination test using beggarweed, *Desmodium tortuosum* (Sw.) DC. (DEDTO), crabgrass, *Digitaria ciliaris* (Retz.) Koel. (DIGSP), guineagrass, *Panicum maximum* Jacq. (PANMA), Johnsongrass, *Sorghum halepense* (L.) Pers. (SORHA), milkweed strangler vine, *Morrenia odorata* (H. & A.) Lindl. (MONOD), pigweed, *Amaranthus retroflexus* L. (AMARE), sicklepod, *Senna obtusifolia* L. (CASOB), Spanish needles, *Bidens pilosa* L. (BIDPI), teaweed or prickly sida, *Sida spinosa* L. (SIDSP) and yellow nutsedge, *Cyperus esculentus* L. (CYPES) alongwith basil, *Ocimum sanctum* L. (OCISA). Germination test was conducted in Petri dish lined with double layered Whatman No. 1 filter paper with 10 seeds of each species replicated thrice and maintained in growth cabinet at 25^{O}C temperature and 75% RH with 14 h light durations. Comparisons were made by using the same test species for germination test using water instead of basil leachate.

In another study, the above species were planted in 8 cm plastic pots in the greenhouse using sandy loam soil collected from field. Basil leachate collected for Petri dish study was used for watering pots and compared with tap water. Emergence of weeds and basil was recorded periodically and final emergence was recorded after three weeks of planting. Both experiments were repeated and pooled data were subjected to ANOVA using SPSS.

Effect of Soil Straw Incorporation of Basil on Weed Seed Emergence

Basil plants raised in pots in the greenhouse were harvested 90 days after sowing (DAS), shade dried and root/shoot/leaves chopped (similar to field discing) for mixing in soil in 1 : 12 ratio (basil : soil). After thorough soil mixing in aluminum trays of 18 x 12" and watering (no drainage), trays were left for a week for the release of allelochemical substances, if any, in the soil. Beggarweed (*D. tortuosum*), Johnsongrass (*S. halepense*), milkweed strangler vine (*M. odorata*), pigweed (*A. retroflexus*), sicklepod (*S. obtusifolia*), Spanish needles (*B. pinnata*), prickly sida (*S. spinosa*) and yellow nutsedge (*C. esculentus*) were planted in aluminum trays with 30 seeds of each species in rows and compared with no basil plant biomass residue. Emergence was recorded three weeks after sowing (WAS) and data were analyzed for emergence percentage.

Basil Competition Study

Basil seeds, were planted in 16 cm tall polystyrene pots containing 1200 g/pot soil of sandy loam texture. When the basil plants attained a height of 5-8 cm, planting of weed species (as used in leachate studies) was done on July 18, 2003 and August 8, 2004. Due to poor germination of *P. maximum* it was replaced with crowfootgrass, *Dactyloctenium aegyptium* (L.) Willd. (DTTAE). Thinning was done a week after emergence to maintain four plants/pot in a replacement series of basil : weeds in 4 : 0, 3 : 1, 2 : 2, 1 : 3 and 0 : 4 with three replicated pots for each species to study intra- and inter-specific competition. The replacement series design has proved successful in measuring the magnitude of competition between two species for different density combinations with a view to maximize resource utilization and crop yield (Harper, 1977). Basil and weed species planted in pots were watered daily and liquid fertilizer was added at weekly intervals. Plant height and fresh weight/pot were recorded 90 DAS for basil and weed species. Relative yield totals (RYTs) and relative crowding coefficients (RCC) for fresh weights were calculated according to the following equations (Harper, 1977) :

$$\text{RYT} = \frac{\text{Fresh weight of basil in mixture}}{\text{Fresh weight of basil in pure stand}} + \frac{\text{Fresh weight of weed sp. in mixture}}{\text{Fresh weight of weed sp. in pure stand}}$$

RYT predicts the competition of the two species for the same resources. Aggressiveness of one species on another was determined by relative crowding coefficient (RCC) using the equation :

$$\text{RCC} = \frac{\text{W1m/W2m}}{\text{W1p/W2p}} \quad \text{or} \quad \frac{\text{W2m/W1m}}{\text{W2p/W1p}}$$

Where, W1m and W2m are fresh weights per pot of species 1 and 2 in 2 : 2 mixture, and W1p and W2p are fresh weights of species 1 and 2 in pure culture. RCC serves as an index of competition when two species are mixed in equal proportions (Jolliffe *et al.*, 1984), but it is poor indicator when two species are in unequal proportions. Aggressivity index (AI) has been found to better correlate the effect of variable density and was calculated by the following equation :

$$\text{AI} = \frac{\text{Fresh weight of basil in mixture}}{\text{Fresh weight of basil in pure stand}} - \frac{\text{Fresh weight of weed sp. in mixture}}{\text{Fresh weight of weed sp. in pure stand}}$$

The RYT and IA data were subject to ANOVA and values were further differentiated by Tukey test.

RESULTS AND DISCUSSION

Effect of Basil Leachate on Weed Seed Germination

Basil leachate reduced the germination of all species, except *P. maximum, S. spinosa, B. pilosa* and *C. esculentus* in Petri dish study (Fig. 1), though differences were not large. Germination of basil was significantly reduced by basil leachate itself. When the data of all species were compared for basil leachate and water, there was no difference in the germination.

Germination varied among weed species and ranged from 27-100% in pots raised with water (Fig. 2); however, no significant differences were observed between basil leachate or water on germination when the combined data were subjected to ANOVA. Basil leachate stimulated emergence of *P. maximum, S. halepense* and *C. esculentus*, but had no effect on *D. ciliaris* (Fig. 2). On the other hand basil leachate reduced the emergence of basil itself, *D. tortuosum*, *M. odorata*, *A. retroflexus*, *S. obtusifolia*, *B. pilosa* and *S. spinosa*. Significant effect on emergence was observed only for *S. halepense* (increased) and *A. retroflexus* (decreased) between basil leachate and water used for irrigation (Fig. 2).

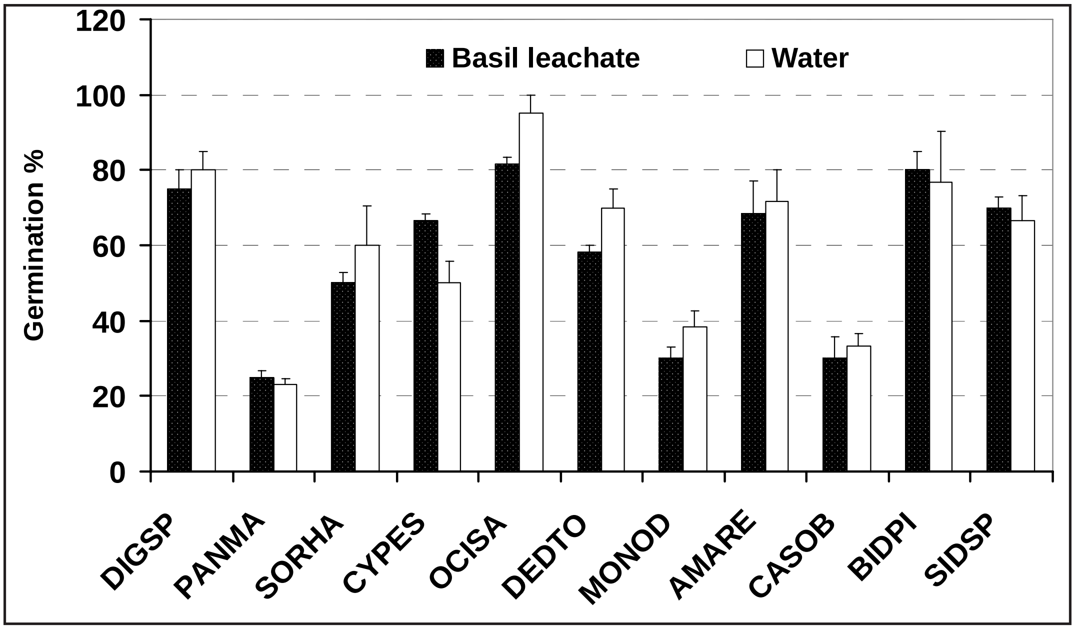

Fig. 1. Effect of basil leachate on weed germination in Petri dish (bars indicate SEm) (DIGSP = *D. ciliaris*, PAMNA = *P. maximum*, SORHA = *S. halepense*, CYPES = *C. esculentus*, OCISA = *O. sanctum*, DEDTO = *D. tortuosum*, MONOD = *M. odorata*, AMARE = *A. retroflexus*, CASOB = *S. obtusifolia*, BIDPI = *B. pilosa* and SIDSP = *S. spinosa*).

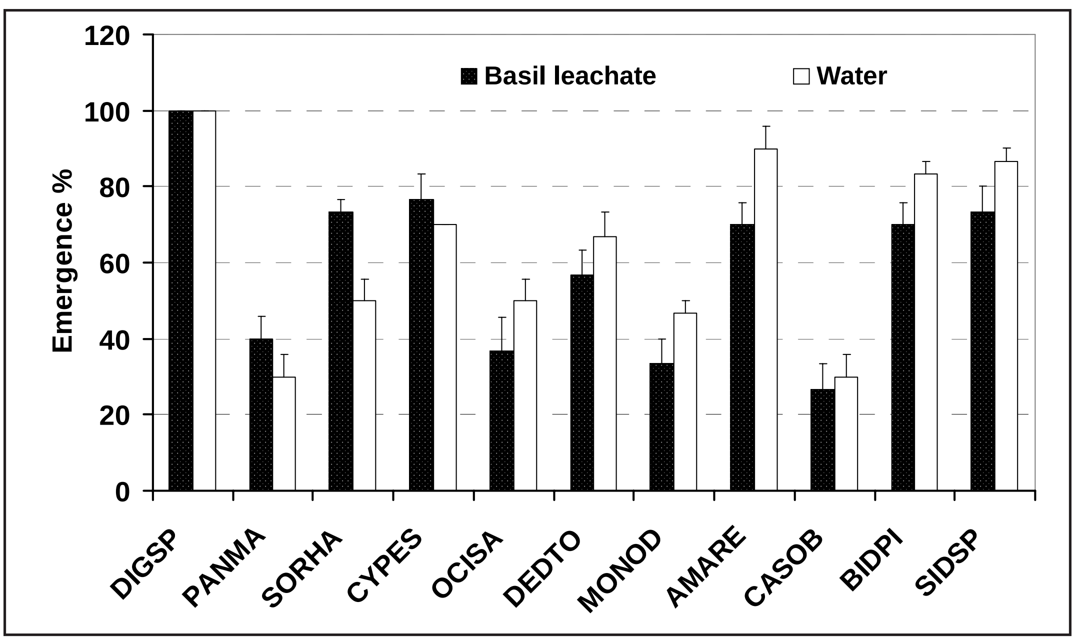

Fig. 2. Effect of basil leachate on weed emergence under pot conditions (bars indicate SEm) (DIGSP = *D. ciliaris*, PAMNA = *P. maximum*, SORHA = *S. halepense*, CYPES = *C. esculentus*, OCISA = *O. sanctum*, DEDTO = *D. tortuosum*, MONOD = *M. odorata*, AMARE = *A. retroflexus*, CASOB = *S. obtusifolia*, BIDPI = *B. pilosa* and SIDSP = *S. spinosa*).

Effect of Soil Straw Incorporation of Basil on Weed Seed Emergence

Basil root/shoot biomass mixed in soil had no effect on the emergence of *D. tortuosum, S. halepense, M. odorata*, *A. retroflexus, B. pilosa*, *S. spinosa* and *C. esculentus* (Fig. 3).

Basil competition study : When growing with basil in 2 : 2 ratio in the pots, the relative crowding coefficient (RCC) was highest for *D. ciliaris* followed by *S. halepense, D. tortuosum* and *M. odorata* which was significantly more than *C. esculentus*, *S. spinosa, B. pilosa* and *S. obtusifolia* (Fig. 4). Lower RCC of basil on *C. esculentus*, *S. spinosa*, *B. pilosa* and *S. obtusifolia* indicated that these weed species were competing with basil for the same resources and reduced its growth more than other weeds when present in equal proportions. When RCC of weeds on basil was computed (Fig. 5), highest values were recorded for *C. esculentus*, which were significantly more than other weed species. *S. spinosa* and *B. pilosa* also had significantly higher RCC values (on basil) than *D. tortuosum, D. ciliaris, S. halepense* and *M. odorata* (Fig. 5).

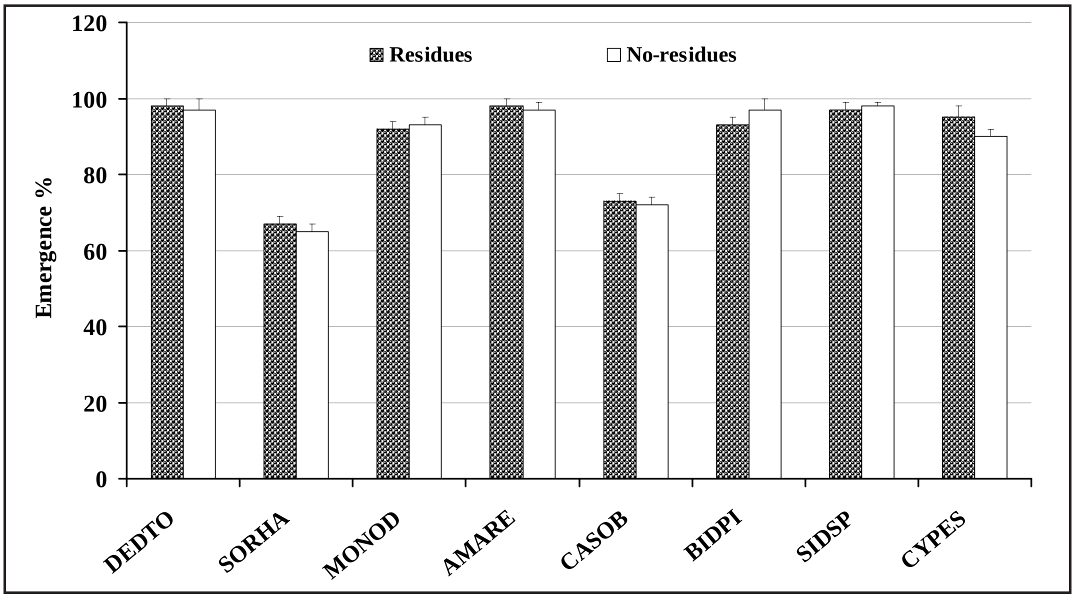

Fig. 3. Effect of soil incorporation of basil plant and root mass on emergence of some weed species (bars indicate SEm) (DEDTO = *D. tortuosum*, SORHA = *S. halepense*, MONOD = *M. odorata*, AMARE = *A. retroflexus*, CASOB = *S. obtusifolia*, BIDPI = *Bidens pilosa*, SIDSP = *S. spinosa* and CYPES = *C. esculentus*).

Significantly, higher relative yield total (RYT) values (1.04) were observed under 1 : 3 ratio (basil : weed species) compared to 2 : 2 or 3 : 1 ratio (0.83 and 0.834, respectively), when data were averaged over species (Fig. 6). Higher RYT values (1.12) were recorded for *D. aegyptium* (averaged over 3 plant ratio) which were significantly more compared to other weed species. The RYT values were similar in 3 : 1 and 2 : 2 ratio of basil and weed species, but lowering the plant population of basil (1 : 3) resulted in increase of RYT. *D. aegyptium, D. tortuosum, S. spinosa* and *C. esculentus* had significant increase in RYT values when their density was thrice that of basil (Fig. 6) compared to other weed species.

Basil aggressivity was significantly affected by composition of plant ratio in the pots and weed species. Significantly lower aggressivity index (AI) was obtained from the fresh weight data (0.525) when one plant of basil was competing with three of weed species in the pots, compared to 3 : 1 ratio (basil : weeds, 0.817) or 2 : 2 ratio (0.747), when data were averaged over species (Fig. 7). Lowest AI (0.49) of basil was recorded on *C. esculentus* which was significantly different from other weed species (data averaged over plant ratio). The decrease in AI of basil was steep with *D. aegyptium, S. spinosa* and *C. esculentus* in the mixed stand when basil ratio decreased from 3 to 1 or 2 : 2 in each of the pot (Fig. 7).

Effect on plant height : Plant height of basil increased significantly when growing with weed species compared to monoculture; however, there was no

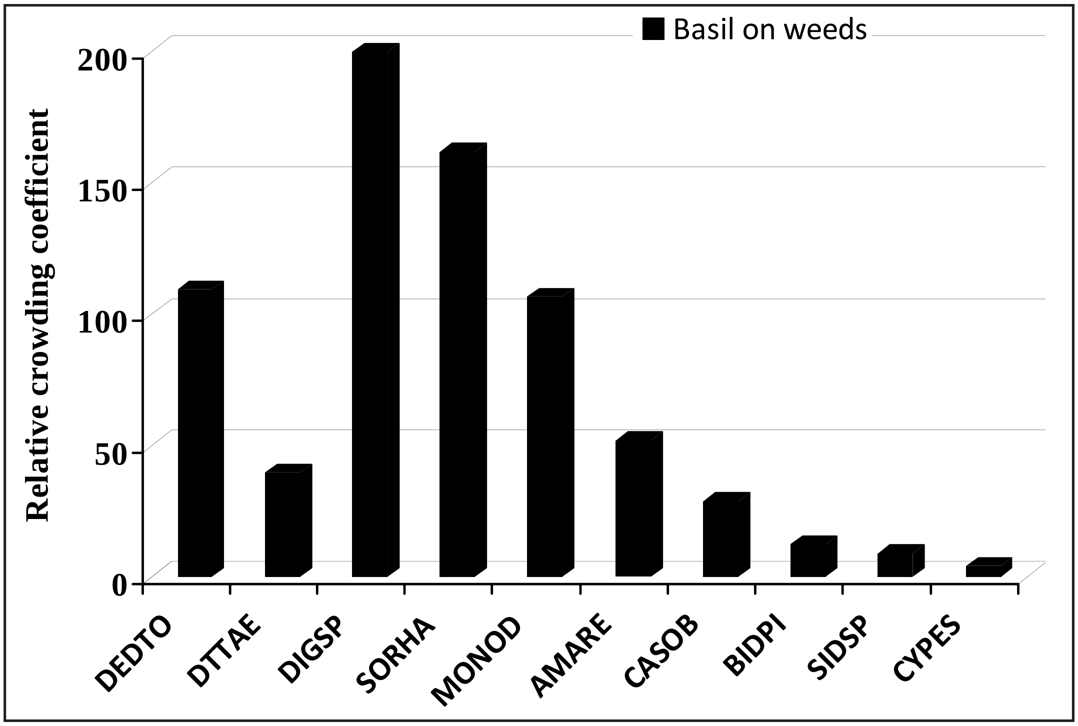

Fig. 4. Relative crowding coefficient of basil on weeds growing in 2 : 2 ratio in pots (DEDTO = *D. tortuosum*, DTTAE = *D. aegyptium*, DIGSP = *D. ciliaris*, SORHA = *S. halepense*, MONOD = *M. odorata*, AMARE = *A. retroflexus*, CASOB = *S. obtusifolia*, BIDPI = *B. pilosa*, SIDSP = *S. spinosa* and CYPES = *C. esculentus*).

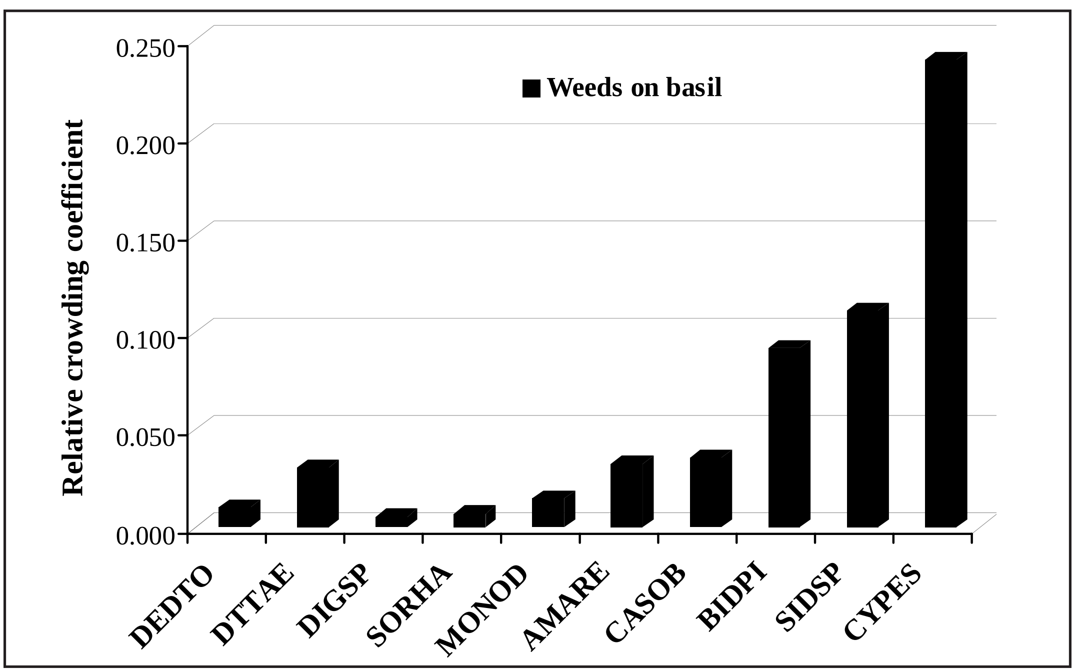

Fig. 5. Relative crowding coefficient of weeds on basil growing in 2 : 2 ratio in pots (DEDTO = *D. tortuosum*, DTTAE = *D. aegyptium*, DIGSP = *D. ciliaris*, SORHA = *S. halepense*, MONOD = *M. odorata*, AMARE = *A. retroflexus*, CASOB = *S. obtusifolia*, BIDPI = *B. pilosa*, SIDSP = *S. spinosa* and CYPES = *C. esculentus*).

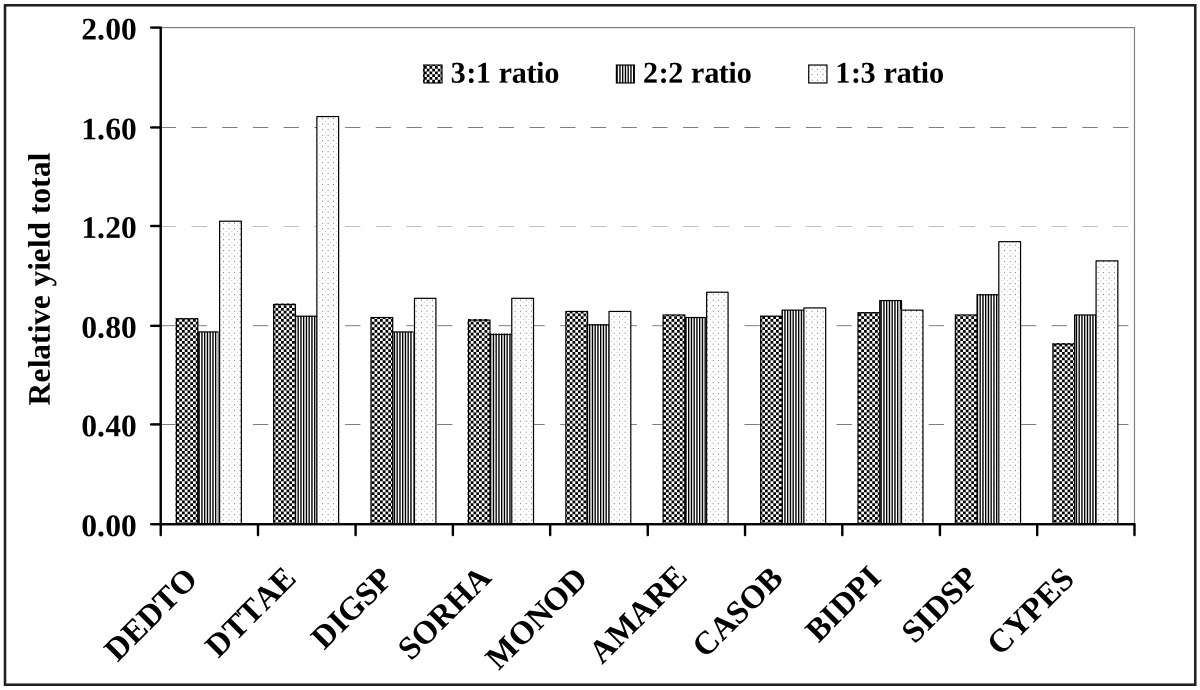

Fig. 6. Effect of basil in different planting ratio with weeds on relative yield totals (DEDTO = *D. tortuosum*, DTTAE = *D. aegyptium*, DIGSP = *D. ciliaris*, SORHA = *S. halepense*, MONOD = *M. odorata*, AMARE = *A. retroflexus*, CASOB = *S. obtusifolia*, BIDPI = *B. pilosa*, SIDSP = *S. spinosa* and CYPES = *C. esculentus*).

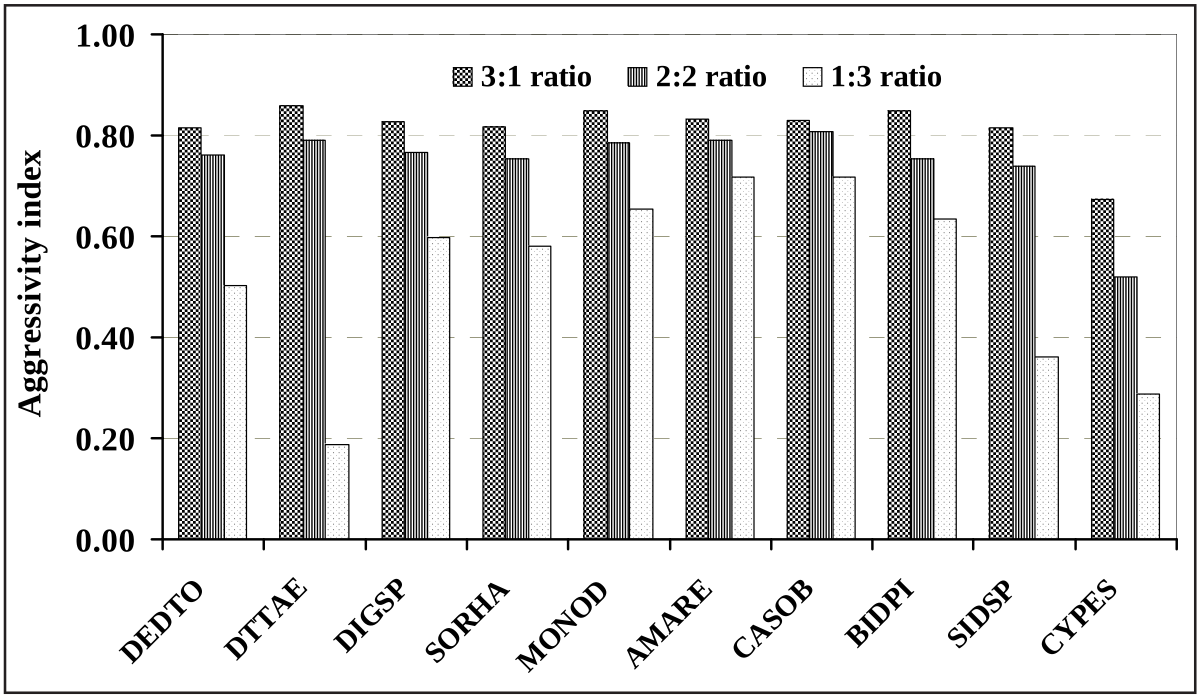

Fig. 7. Aggressivity of basil on weeds at different plant ratio in the pots (DEDTO = *D. tortuosum*, DTTAE = *D. aegyptium*, DIGSP = *D. ciliaris*, SORHA = *S. halepense*, MONOD = *M. odorata*, AMARE = *A. retroflexus*, CASOB = *S. obtusifolia*, BIDPI = *B. pilosa*, SIDSP = *S. spinosa* and CYPES = *C. esculentus*).

difference in plant height when 1, 2 or 3 plants of basil were growing with weeds, data averaged over plant ratio (Fig. 8). Basil plant height was not affected by weeds as revealed by one-way ANOVA with Tukey test when data were averaged over species. Some variations though were observed under different plant ratio of basil and weeds. Interaction of plant ratio and weed species was significant on plant height of weeds as affected by basil (Fig. 9). Plant height of weeds increased from 12, 16, 23 and 70 cm, respectively when 3, 2, 1 and no basil plants were growing, data averaged over species. Weeds growing alone had highest plant height which was significantly more compared to growing with basil plants. Plant height of *C. esculentus* was unaffected by basil at any plant ratio in the mixture (Fig. 9). Decreasing the ratio of basil from 2 to 1 resulted in significant increase in plant height of *D. tortuosum*, *D. ciliaris* and *S. halepense*, whereas even single plant of basil reduced plant height of *D. aegyptium*, *S. spinosa*, *A. retroflexus* and *M. odorata*.

Basil leachate reduced the germination of *D. ciliaris*, *S. halepense*, *D. tortuosum*, *M. odorata*, *A. retroflexus*, *S. obtusifolia* and *O. sanctum* under the laboratory conditions (Fig. 1) and *D. tortuosum*, *M. odorata*, *A. retroflexus*, *S. obtusifolia*, *B. pilosa* and *S. spinosa* under greenhouse conditions (Fig. 2); however, the differences were not large enough. Sharma and Singh (2003) reported that 7.5% leaf extract of basil inhibited germination of radish, *A. retroflexus*, *B. pinosa* and *P. maximum*, but the same effect was absent when basil leaf, root and shoot biomass was mixed in soil in 1:12 ratio in the present study (Fig. 3). Under control conditions, germination of 43, 17 and 13% for *A. retroflexus*, *B. pinosa* and *P. maximum* was low (Sharma and Singh, 2003) to draw any logical conclusion. Gannon *et al*. (2006) reported that germination and growth of *Poa annua*, *Eleusine indica*, *Lamium amplexicaule*, *Digitaria sanguinalis* and *Lolium perenne* evaluated in *Eremochloa ophiuroides* soil leachates, leaf debris, and aqueous leaf extracts under laboratory and greenhouse experiment were not inhibited compared to non-fertilized control. Malik *et al*. (2006) reported that wild radish and rye cover crops without herbicides reduced total weed density by 35 and 50%, respectively. Cover crops and herbicides further improved control, indicating optimization of weed control by use of cover crops and

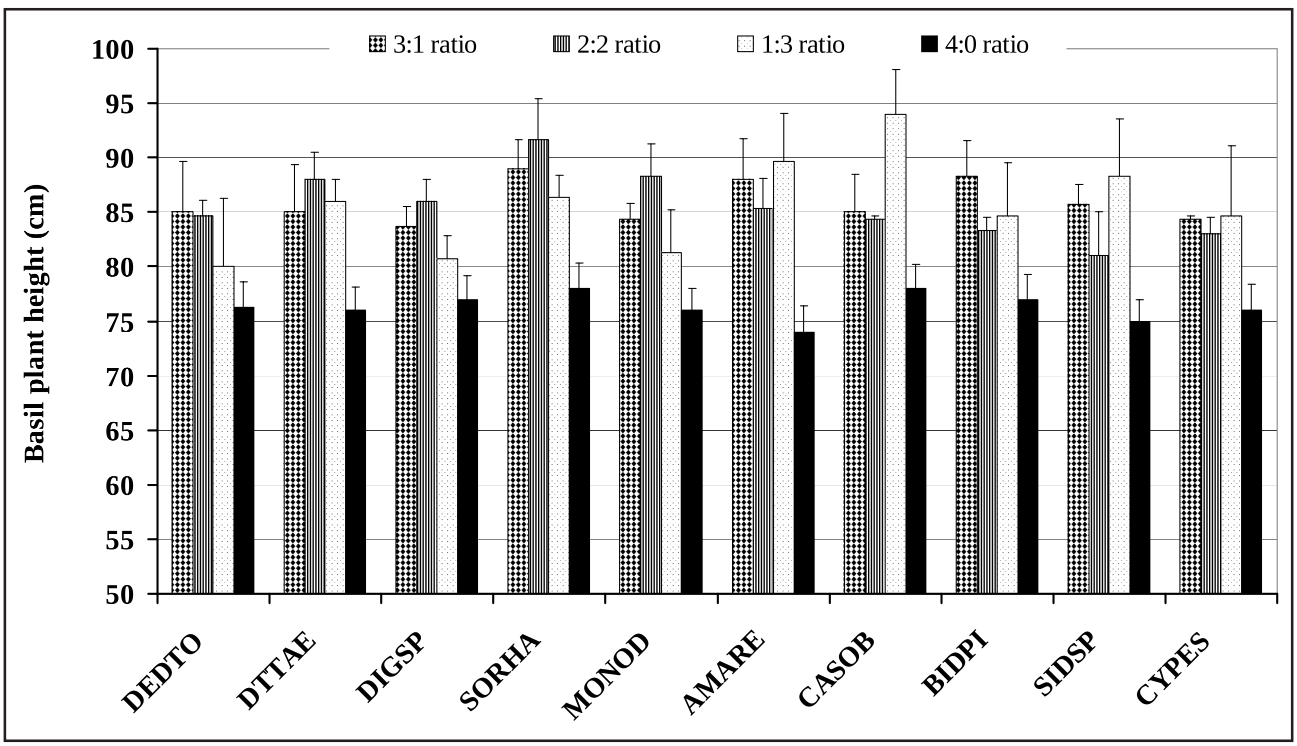

Fig. 8. Effect of weeds on plant height of basil in pots (DEDTO = *D. tortuosum*, DTTAE = *D. aegyptium*, DIGSP = *D. ciliaris*, SORHA = *S. halepense*, MONOD = *M. odorata*, AMARE = *A. retroflexus*, CASOB = *S. obtusifolia*, BIDPI = *B. pilosa*, SIDSP = *S. spinosa* and CYPES = *C. esculentus*).

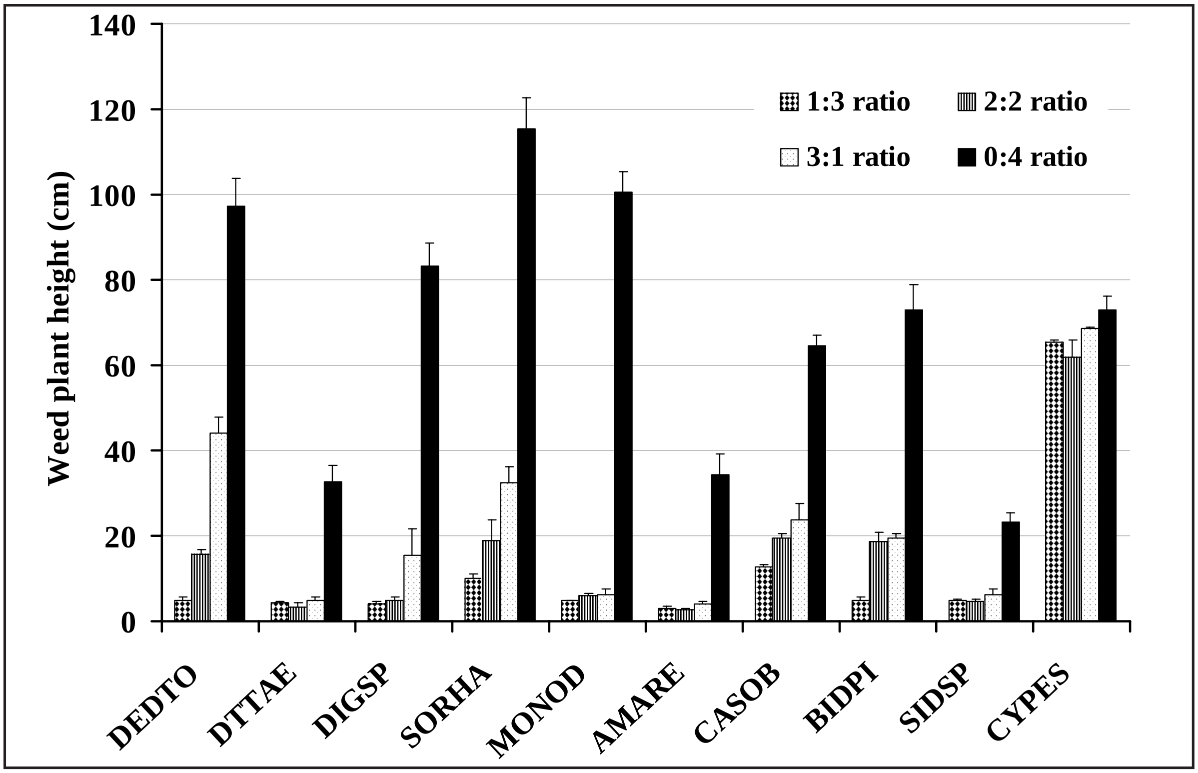

Fig. 9. Effect of basil on plant height of weeds in pots (DEDTO = *D. tortuosum*, DTTAE = *D. aegyptium*, DIGSP = *D. ciliaris*, SORHA = *S. halepense*, MONOD = *M. odorata*, AMARE = *A. retroflexus*, CASOB = *S. obtusifolia*, BIDPI = *B. pilosa*, SIDSP = *S. spinosa* and CYPES = *C. esculentus*).

herbicides together. On the other hand, *E. ophiuroides* leachate and leaf debris which had no effect on several weed species, but reduced radish shoot weight by 49 and 64%, respectively, compared to control when 6 and 9 mg leaf debris per g soil was incorporated (Gannon *et al.*, 2006). Allelopathic evidence of *Secale cereale* residues and extracts has been reported by several workers including Barnes and Putnam (1986). Brecke and Shilling (1996) and Hoffman *el al*. (1996) reported that inhibitory effect on emergence and growth of *S. obtusifolia* and *E. crusgalli* was more with root residues of *S. cereale* compared to its shoot residues. Similarly, differential effect on the emergence and growth of *Amaranthus powellii* by root and shoot of buckwheat (*Fagopyrum esculentum*) was reported by Kumar *et al*. (2009); the role of soil fertility was also significant in this case. On the other hand, basil leachate had stimulatory effect on the germination of *P. maximum, C. esculentus, B. pinosa* and *S. spinosa* under laboratory conditions (Fig. 1) and *P. maximum, S. halepense* and *C. esculentus* under greenhouse conditions (Fig. 2). Kahl (1987) found that leaf extracts of *B. pilosa* had a stimulatory effect on the germination of maize, whereas different water extracts of maize showed an indifferent influence on the germination and seedling growth of *B. pilosa*. Khanh *et al*. (2009) also reported allelopathic effect of *B. pilosa*. Basil leachate inhibited the germination of basil itself both under laboratory and greenhouse conditions (Figs. 1 and 2). Autotoxicity of clover is well established (Putnam, 1985), where allelochemicals have detrimental effect on the plants of same species. In the large pots maintained for five years with basil plants in the greenhouse at the Citrus Research and Education Center had some weed species growing in the pots. Had there been any allelopathy, the weed species would not have thrived in the close vicinity of basil. Tamak *et al*. (1994) reported that a 10% extract of straw and rice stubbles completely inhibited the germination of *P. minor* under lab conditions. Had that been true under field conditions, there would have been no infestation of *P. minor* in rice-wheat rotation areas as rice straw is incorporated in the field prior to wheat sowing. Contrarily, highest occurrence of *P. minor* was found in the rice-wheat rotation areas (Singh *et al.*, 1995). These kinds of erroneous interpretations led to nowhere as the metabolites from the leachate (plant extract) of one plant inhibit the emergence of other plants and sometime of its own species under controlled conditions, but do not hold true under field conditions.

Suppression of *E. crusgalli* by some rice cultivars was attributed to allelopathic interference (Olofsdotter *et al*., 1995); however, Mattice *et al*. (2001) and Gealy *et al*. (2005) suggested contribution of both competition and allelopathy. Dhima *et al*. (2007) reported that barley and oats were more competitive with common vetch than wheat. The relative crowding coefficient (RCC), when basil was growing in equal proportions with weeds was lowest on *C. esculentus* (Fig. 4), whereas the RCC of *C. esculentus* on basil (Fig. 5) was highest suggesting their competition for the same resources and affecting the growth of each other. Though allelopathic effect of extracts and residues of *C. esculentus* was reported on corn and soybean (Drost and Doll, 1980). Extracts of *C. esculentus* tubers and foliage not only inhibited the colony size of ectomycorrhiza (*Boletus maxaria*), but also significantly reduced germination of lettuce (*Lactuca sativa*) and emergence of corn (*Zea mays*) when tubers were planted four weeks before corn sowing (Reinhardt and Bezuidenhout, 2001). Allelopathic effect of *S. halepense* on wheat was also demonstrated (Roth *et al*., 2000) under field conditions. A high RCC value (basil on *S. halepense*) and low RCC of *S. halepense* on basil in the present study (Figs. 4 and 5) showed that the effect was more of competitive suppression rather than any visible allelopathic effect. Increase in the RYT values when the population of basil in the mixture decreased from 3 to 2 and one plant/pot showed the smothering effect of basil on weeds (Fig. 6) which was also evident from aggressivity (AI) of basil on weeds (Fig. 7). Increased RYT of *D. aegyptium*, *D. tortuosum*, *S. spinosa* and *C. esculentus* in 3 : 1 ratio with basil indicated their suppression under higher density of basil and utilization of resources better than they outnumbered basil in the mixture. Due to its spreading habit highest RYT in *D. aegyptium* supports the advantage of system (growing in association with basil in 3 : 1 ratio) in exploiting environmental resources and accumulating greater growth and fresh weight. Inderjit *et al.* (2001) found that root length suppression of *Lolium perenne* was wheat density dependent, but the same was not true for shoot length. Also density of *L. perenne* had no effect on wheat seedling growth early in the season. Plant height and fresh weight/plant of basil increased when one plant of basil was competing with three of weed species (Fig. 8). Significant increase in plant height of weeds, except *C. esculentus* when growing alone compared to mixture with basil further supports the competing role of basil on these weed species (Fig. 9).

A lot of work has been published on allelopathic effect of one species on other through bioassay under laboratory or greenhouse conditions, but only few made the results repeatable under field conditions. Great care should be taken in interpretation of such results as there is a complex situation where several factors play important role. Under natural system thousands of secondary products/metabolites are produced by plants, microbes and animals as part of the biological system which affects the emergence and growth of plants in their immediate vicinity. Allelopathy holds great potential as an alternate weed management system, when used alone or in combination with other practices, reducing greater reliance on herbicides and lowering the undesired effects of chemical weed control. An ideal allelopathic plant should be fast growing to produce large biomass for allelochemicals, has no potency to become a pest, should have annual growth cycle, succulent and fast degradable, with low water and nutrient requirements (maintenance free) and provides no refuge to insects and pests. Basil plants possess many of these desired traits, but no alleopathic evidence on weeds was found in the present study.

ACKNOWLEDGEMENTS

Authors wish to thank Mr. Gary Test, Sr. Lab Technician for assistance in conducting research and University of Florida, Citrus Research and Experiment Center for providing the facilities.

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