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Synergy of Tank Mix Application of Herbicides on Canada Thistle (*Cirsium arvense*) under Non-cropped Situations

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ABSTRACT

Field studies were carried out under non-cropped situations using tank mix applications of some herbicides against Canada thistle (*Cirsium arvense*) during 2007-08 and 2008-09. Tank mix applications of carfentrazone 20 g/ha with glyphosate 1.0% (0.75% repeat year) plus 0.25% non-ionic surfactant (NIS) provided 95 (95) and 87% (82) control of Canada thistle compared to 95 (97) and 83% (82) control by glyphosate alone at 2.0+0.25% NIS, 8 and 13 weeks after treatment (WAT), respectively. Carfentrazone alone was not effective. In another experiment, tank mix applications of carfentrazone 20 g/ha+glyphosate 0.75+0.25% NIS+2,4-D amine 500 g/ha provided 98, 99, 96 and 89% control of Canada thistle compared to 85, 95, 92 and 79% control by tank mixing of 2,4-D 500 g/ha+glyphosate 1.0+0.25% NIS and 89, 92, 88 and 78% control by glyphosate alone 2.0+0.25% NIS, respectively, at 21, 42, 56 and 75 DAT. The mortality of Canada thistle was similar when glyphosate 1.0 or 1.5% was tank mixed with 20 or 40 g/ha of carfentrazone. Effect of 2, 4-D amine was significantly lower when used alone or tank mixed with carfentrazone compared to their mixture with glyphosate. The effect of herbicides was significantly higher in the second year compared to first year of spraying. Tribenuron alone at 25 g/ha+0.25% NIS or its tank mixture at 20 g/ha with 2,4-D ester 250 g/ha, metsulfuron 4 g/ha or carfentrazone 20 g/ha was not effective against Canada thistle. Similarly, tank mix applications of metsulfuron 2 or 4 g/ha with 2,4-D 250 or 500 g/ha failed to satisfactorily control Canada thistle. Glyphosate 1.0% alone or with metsulfuron 4 g/ha provided similar control of Canada thistle, but effect was significantly lower than alone application of glyphosate at 2.0+0.25% NIS.

Key words : Carfentrazone, glyphosate, 2,4-D, metsulfuron, tribenuron

INTRODUCTION

Canada thistle [*Cirsium arvense* (L.) Scop.] has been reported as a major perennial weed of many crop, pasture, roadside, lawn, range/wasteland and natural areas in many countries (Holm *et al.*, 1977). Canada thistle is native to Eurasia but is now considered to be naturalized worldwide. It figured in the top 10 weeds' list of Europe and a serious weed throughout North America (Moore, 1975). Due to its aggressive nature, deep rooted system and regenerative capacity with creeping rhizomes and germination from seed, it causes greater yield loss than any other broadleaf weed and is very difficult to control in a single year. Canada thistle plants have either male or female flowers, but not both on the same plant and is a prolific seed producer. Each flower head can produce 50 seeds and one female plant can produce 1500 to 5300 seeds (Moore, 1975). Multiple plants produce an average of 64,300 viable seeds/m^2 in Australia (Amor and Harris, 1974), which can remain viable in the soil for 20 years. Seed germination ranged from 52-97% for seeds collected from 40 pastures infested sites in Australia and some seed was also produced when the male and female plants were separated by 390 m (Amor and Harris, 1974).

The presence of pappus (tuft of hairs on seed) helps its easy dissemination by wind and water and with little dormancy seed can germinate shortly after infestation in new areas. Mechanical methods are not successful as Canada thistle has deep creeping rhizomes and one plant can produce 6 m of rhizome per year and can have 200 buds, making it a serious invader and difficult-to-control weed. It has more below ground than above ground growth. The average plant height varies from 2 to 5 ft, but roots can move upto 17 ft in horizontal and 20 ft in vertical direction, although most roots are confined to the top 40 cm soil depth. Tillage operations can also aid its root dispersal and frequent mowing/chopping is required to exhaust its stored food reserve in the roots.

A population of 20 plants/m^2 of Canada thistle can reduce barley (*Hordeum vulgare* L.) yields upto 34% (O'Sullivan *et al.*, 1982). Yield reduction in winter wheat ranged from 28 to 71% with dense patches of Canada thistle and mean reduction of 49% averaged from 11 experimental sites over two years period (McLennan *et al*., 1991). Canada thistle not only causes extensive crop losses through competition, its allelopathic effects have been observed on germination and growth (Bendall, 1975; Stachon and Zimdahl, 1980). Canada thistle has a strong competitive effect on winter wheat, and grain yield reduction was positively correlated to the number of Canada thistle plants per unit area (Mamolos and Kalburtji, 2001). Canada thistle has been found to reduce corn yield (*Zea mays* L.) by 57% and soybean yield (*Glycine max* L.) by 91% (Elakkad and Behrens, 1976). It is a major weed of wheat, barley, mustard, chickpea and other winter season crops of Indo-Gangetic plains. Other than crops, it is also widespread in uncultivated areas under high soil moisture conditions (Yaduraju and Ahuja, 1991). Significantly higher infestation of Canada thistle was observed in eastern than western zone of Haryana (Singh *et al*., 1995) where soil moisture/rainfall was higher and greater area under double cropping system with assured irrigation. Not only Canada thistle competes vigorously with wheat and other crops, but also hampers manual harvesting and other agricultural operations due to the presence of spiny, toothed leaves. Starting in patches it overcomes large field swaths both under cultivated and uncultivated areas. Because of its severe damages both in cultivated and uncultivated areas (pasture, range, wasteland and forest) and its unpalatability to animals, it has been included in the list of noxious weed in US, Canada, Australia, New Zealand and Brazil and monitored in many other countries.

Canada thistle control in range, pasture and non-crop areas has been reported by picloram, clopyralid, dicamba, dicamba + diflufenzopyr, 2,4-D amine, triclopyr, chlorsulfuron, metsulfuron, glyphosate, and various combinations of these herbicides (Kirkland, 1977; O'Sullivan and Kosssatz, 1984; Gupta *et al*., 1987; Singh and Malik, 1992; Yaduraju and Das, 2002; Dewey *et al*., 2006). Canada thistle control was 89% with the sulfonylurea herbicide metsulfuron under green house conditions, whereas primisulfuron, chlorsulfuron and tribenuron provided >70% control (Sprague *et al*., 1999). Application of glyphosate at rosette stage than bud stage required lower herbicide dose and achieved better control and resulted in consistently lower shoots in second and third year of treatment (Hunter, 1996).

Glyphosate efficacy is considerably lowered with delayed application (increased growth stage of weeds). Tank mix application of glyphosate with carfentrazone has been found to increase weed control efficacy and increased weed spectrum in tea gardens and provided similar control to the recommended practices of tank mix application of glyphosate with 2,4-D (Ilango, 2003; Rajkhowa *et al*., 2005). Carfentrazone has been recommended for the control of broadleaf weeds in cereals and has no residual effect (Singh *et al*., 2004, Punia *et al*., 2006; Walia and Singh, 2006) and is compatible in mixture with graminicides (Singh and Singh, 2005). Considering the availability of herbicides in the local market, field experiments were planned under uncultivated and fallow fields highly infested with Canada thistle and field bind weed (*Convolvulus arvensis* L.) to evaluate tank mix applications of glyphosate, carfentrazone, 2,4-D and tribenuron for their efficacy when applied alone or as tank mixing.

MATERIALS AND METHODS

Field studies were carried out during the winter seasons of 2007-08 and 2008-09 at Agronomy Farm of CCS Haryana Agricultural University, Hisar. The soil of the experimental field was sandy loam in texture, low in OC and available N, medium in P_2O_5 and high in K_2O with a pH range of 8.2 to 8.5. The fields were infested with natural population of Canada thistle for the last several years. Three experiments were conducted in separate fields.

Experiment 1 : The uncultivated field was infested with Canada thistle, field bind weed, meadow pea (*Lathyrus aphaca* L.), *Ageratum conyzoides* (Bill goat weed) and other weed species. Carfentrazone 40 g/ha alone, carfentrazone 20 g/ha+glyphosate 1.0%, carfentrazone 40 g/ha+glyphosate 1.0% and carfentrazone 20 g/ha+glyphosate 1.5% was compared with glyphosate 2.0% and control in a plot size of 77 x 6 m with three replications. A non-ionic surfactant (NIS) at 0.25% was used with glyphosate. Herbicides were sprayed on December 3, 2007 using 200 l water/ha with backpack sprayer fitted with 3 nozzle boom flat fan nozzles. The plants were in rosette stage (15 to 20 cm in height) at the time of spraying. Visual mortality was recorded 2 to 13 weeks after treatment (WAT). During the second year, plants were sprayed on January 3, 2009 and glyphosate was used at lower rates (0.75 and 1.0%) in the mixture compared to first year of the experiment. The plants ranged from rosette to early bud stage at the time of spraying. Visual mortality was recorded periodically on 0-100 scale, where 0=no effect and 100=complete mortality.

Experiment 2 : Canada thistle growing in *Saccharum munjo* planted (burnt after harvesting) field was sprayed on December 15, 2007 at rosette stage with carfentrazone 40 g/ha, glyphosate 2.0+0.25% NIS, 2,4-D amine 1.0 kg/ha applied alone and tank mix applications (carfentrazone+glyphosate 20 g+1.0%, 40 g+1.0%, 20 g+1.5% and carfentrazone+2,4-D amine 20 g+500 g, 20 g+750 g, 20 g+1000 g/ha and glyphosate+carfentrazone+2,4-D amine 0.75%+20 g+500 g/ha) in a plot size of 12 x 3 m replicated thrice. Glyphosate treatments were made with 0.25% NIS. Visual observations were recorded at 9, 15, 21 and 75 days after treatment (DAT). Plants were sprayed at rosette stage in the first year and flowering initiation stage in the second year. The field was dominated by Canada thistle.

Experiment 3 : In a fallow field (millets-wheat rotations) with heavy infestation of Canada thistle and field bind weed, spray treatments of metsulfuron 4 g/ha, 2,4-D ester 500 g/ha, carfentrazone 20 g/ha, glyphosate 1.0 and 2.0%, tribenuron 25 g/ha alone and tank mix of metsulfuron+2,4-D ester 2+250 g, 2+500 g, 4+250 g, 4+500 g/ha, metsulfuron+carfentrazone 4+20 g/ha, metsulfuron+glyphosate 4 g+1.0%, 2,4-D+carfentrazone 250+20 g/ha, tribenuron+carfentrazone 20+20 g/ha, tribenuron+ metsulfuron 20+4 g/ha and tribenuron+2,4-D 20+250 g/ha were compared with untreated check in a randomized plot with three replications in a plot size of 18 x 3 m. Herbicides were sprayed on December 25, 2007 delivering 250 l spray volume with backpack sprayer fitted with 3 flat fan nozzle boom. The Canada thistle plants at spray were at rosette stage. A non-ionic surfactant (0.25%) was added to all treatments of glyphosate, metsulfuron and tribenuron. Visual observations on mortality were recorded 1, 3, 5 and 9 WAT. The experiment was not repeated for the second year because of poor response of the mixtures.

Data on per cent mortality for individual year and experiment were subjected to ANOVA using SPSS and means separated by Tukey's test. Original data are presented in figures with standard error of means (SEm).

RESULTS AND DISCUSSION

Experiment 1 : Carfentrazone alone was not effective against Canada thistle as the control was less than 20% at early stage of spraying and treated plants completely recovered 4 WAT (Fig. 1). Effect of glyphosate 2% was slow and significant control was observed after two weeks. However, tank mix application of glyphosate with carfentrazone inflicted greater damage to Canada thistle plants even at lower rates of glyphosate. Efficacy of glyphosate alone was greater during the second year compared to first year of application. Glyphosate 0.75% tank mixed with carfentrazone 20 g/ha provided similar control to that of its higher rates in the mixture or when applied alone (Fig. 1). Canada thistle control started to decline after eight weeks due to new growth.

Experiment 2 : There was 10-15% higher mortality of Canada thistle (data averaged over treatments) in the second year over first year, hence data were analyzed separately and presented in Fig. 2. Glyphosate 2% provided 15 and 37% mortality of Canada thistle compared to 57-78 and 67-87% control with tank mix of carfentrazone at 1 and 2 WAT, respectively, in the first year. Highest mortality of Canada thistle was recorded with tank mix of glyphosate at 0.75+0.25% NIS+carfentrazone 20 g+2,4-D 500 g (Fig. 2). Glyphosate alone (2%) at 21 DAT provided 6-10% lower control of Canada thistle compared to its tank mixing with carfentrazone, though it was statistically similar. Carfentrazone failed to increase Canada thistle control when mixed with 2,4-D amine as the highest control of 68% was achieved at 42 DAT when carfentrazone 20 g was mixed with 1.0 kg of 2,4-D; the control was statistically similar to alone application of 2,4-D amine (58%). Tank mixing of 2,4-D amine 500 g/ha+glyphosate 1.0% with 0.25% NIS provided similar control to that of glyphosate 2+0.25% NIS. New plants started to emerge after 21 days of treatment and the overall control decreased on 56 and 75 DAT; the decrease was lower with tank mix of glyphosate+2,4-D +carfentrazone (Fig. 2).

During the second year, the control of Canada thistle was 10% higher at 21, 42 and 75 DAT and 15% more at 56 DAT compared to first year of treatments, when data were averaged over treatments, for respective durations (Fig. 2). Application of 2,4-D amine alone or its tank mixing with carfentrazone provided 67 to 78% control of Canada thistle 21 DAT which was significantly higher over previous year, though addition of carfentrazone to 2,4-D amine failed to synergize the

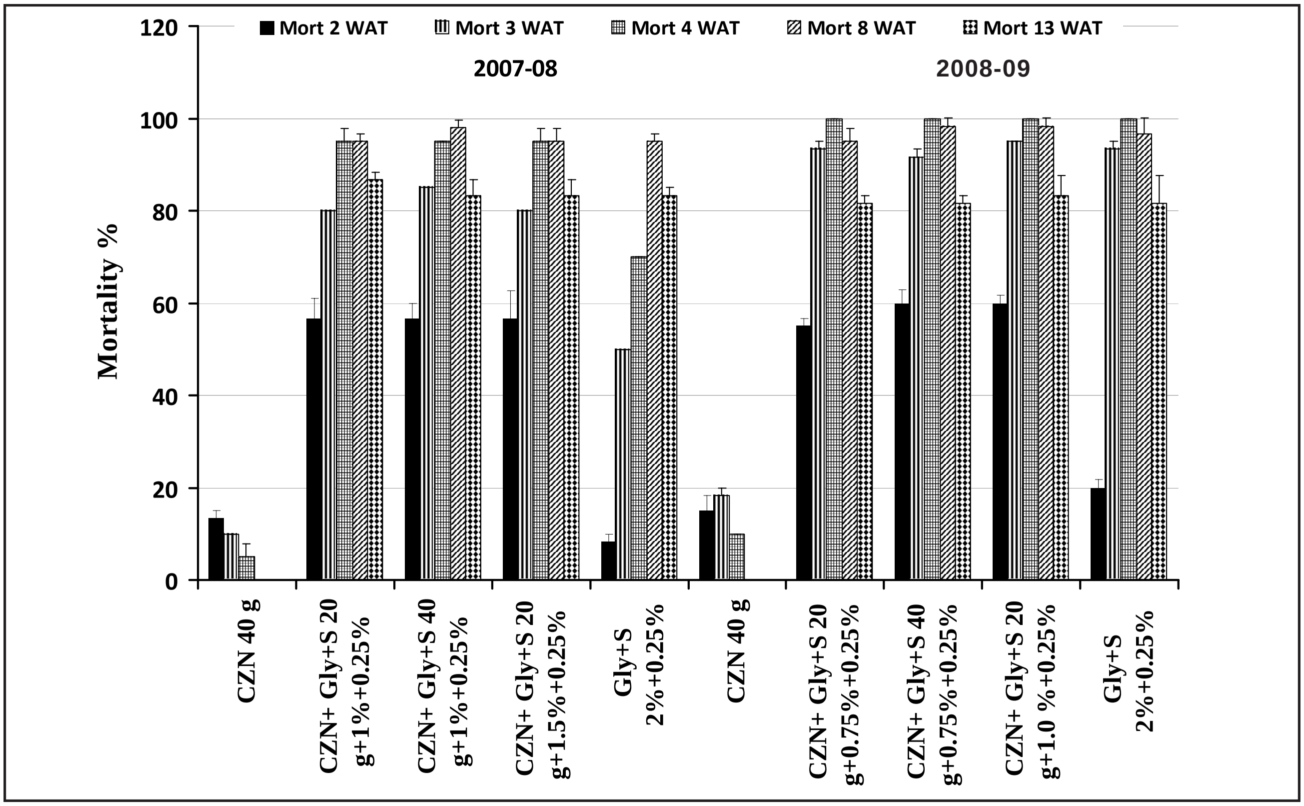

Fig. 1. Canada thistle mortality by alone and tank mix application of glyphosate and carfentrazone for two years (CZN–Carfentrazone, Gly–Glyphosate). Error bars indicate SEm.

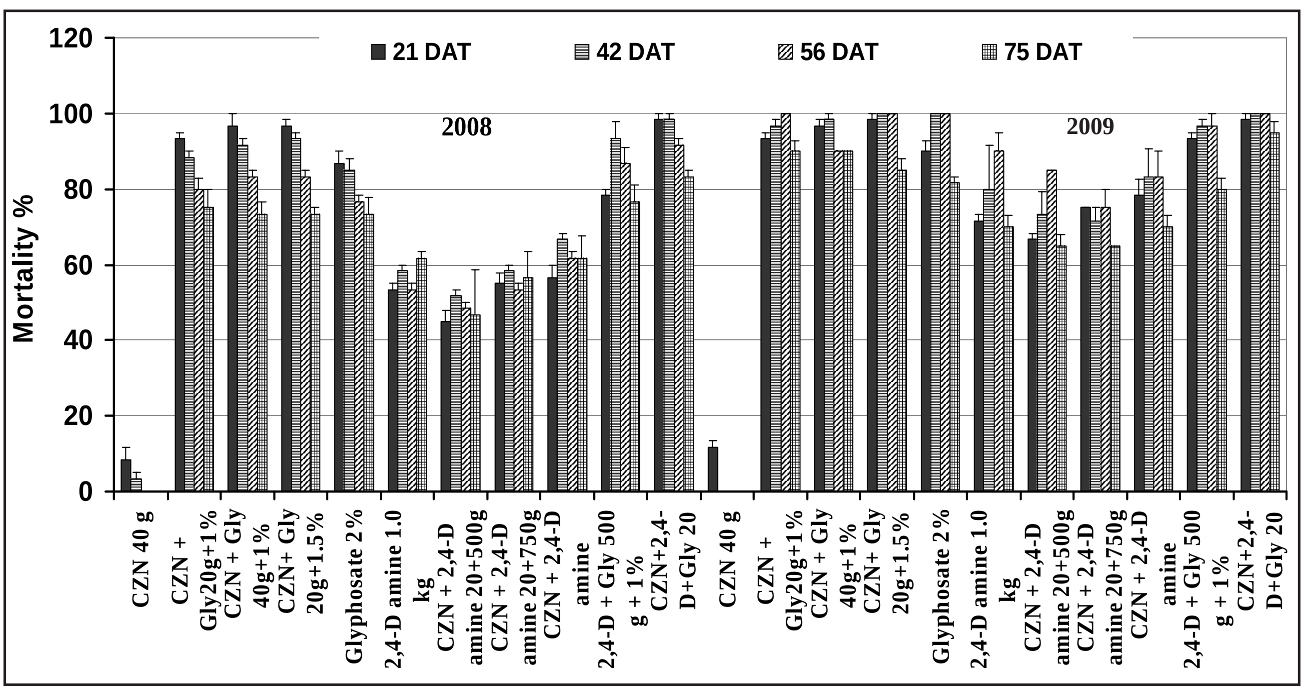

Fig. 2. Potency of alone and tank mix applications of carfentrazone, glyphosate and 2,4-D amine against Canada thistle during 2008 and 2009 (CZN–Carfentrazone, Gly–Glyphosate). Error bars indicate SEm.

potency of the mixture as observed by tank mix of carfentrazone with glyphosate. Tank mix of glyphosate with carfentrazone provided 93 to 100% control of Canada thistle 21 to 56 DAT compared to 72 to 90% control with glyphosate alone at 2% concentration, respectively. Similarly, tank mix application of 2,4-D 500 g+glyphosate 1.0% provided 93 to 97% control of Canada thistle at 21, 42 and 56 DAT; the control, however, decreased 75 DAT to 80% which was significantly lower than tank mix application of 2,4-D, glyphosate+carfentrazone (Fig. 2). Carfentrazone alone had no control of Canada thistle as only 12% plant suppression was observed 21 DAT which was nullified later on.

Experiment 3 : Carfentrazone+2,4-D ester (20 +500 g/ha) provided 50% control of Canada thistle 7 DAT and was better than their alone application; however, it decreased later on and failed to provide satisfactory control of Canada thistle (Fig. 3). Carfentrazone alone 20 g/ha provided 18% growth reduction of Canada thistle 7 DAT and no effect was observed later on. Metsulfuron 4 g/ha+glyphosate 1.0 +0.25% NIS provided similar control to that of alone application of 2% glyphosate 3 WAT. Tribenuron alone or its tank mix applications with carfentrazone, metsulfuron or 2,4-D ester were not effective against Canada thistle. Similarly, tank mix application of metsulfuron with 2,4-D ester failed to provide significant control of Canada thistle; the effect was slow and maximum control was recorded 9 WAT, but not more than 48% at any treatment combinations (Fig. 3). Highest control of Canada thistle was observed with glyphosate 2% at 7 WAT which was significantly more than tank mix application of glyphosate+metsulfuron (1.0%+4 g/ha) or glyphosate 1.0% (Fig. 3). 2,4-D ester 500 g/ha provided maximum 50% control of Canada thistle 7 WAT, the effect decreased significantly 9 WAT. Due to new emergence and re-growth of treated plants, Canada thistle control was greatly decreased 9 WAT and only tank mix of

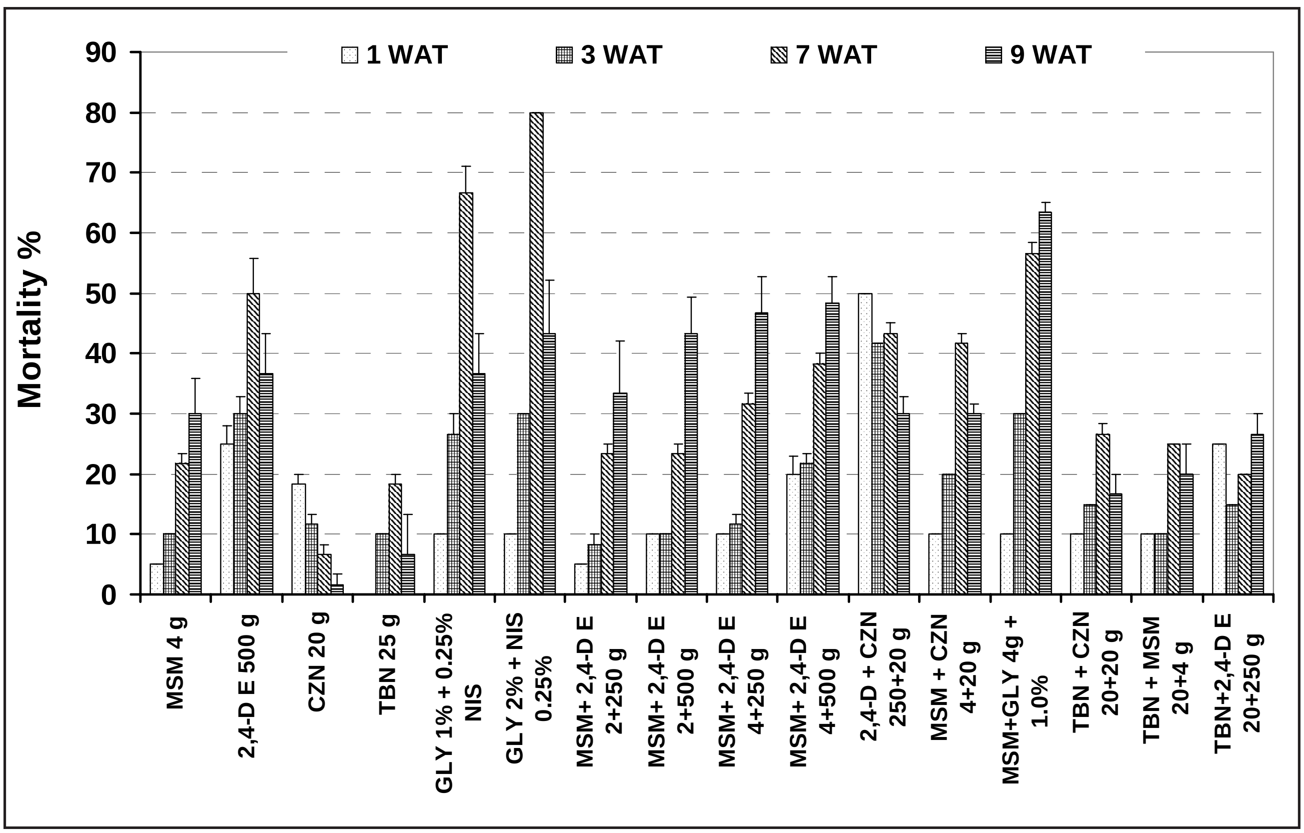

Fig. 3. Efficacy of alone or tank mix application of tribenuron, metsulfuron, carfentrazone, 2,4-D ester and glyphosate against Canada thistle during 2008 (MSM–Metsulfuron, CZN–Carfentrazone, TBN–Tribenuron, GLY–Glyphosate). Error bars indicate SEm.

metsulfuron+glyphosate (4 g/ha+1.0%+0.25% NIS) recorded 63% control which was significantly better than any other treatments.

Tank mix application of glyphosate with carfentrazone greatly enhanced the mortality of Canada thistle and provided mortality similar to double the rates of glyphosate when used alone (Figs. 1 and 2). Moreover, effect of tank mix was rapid than alone application of glyphosate. Similarly, increased efficacy was observed with tank mix applications of glyphosate with 2,4-D on Canada thistle (Fig. 2). Increased weed mortality and lower weed dry weight with tank mix applications of carfentrazone+glyphosate, 2,4-D+glyphosate and glyphosate+carfentrazone+2,4-D were reported against tea weeds by Ilango (2003) and Rajkhowa *et al*. (2005). Tank mix applications of glyphosate 720 g with 2,4-D Na 1120 g/ha was recommended for broad-spectrum weed control in tea gardens, but tank mix applications of carfentrazone with glyphosate were found more promising as carfentrazone had no residual effect (Ilango, 2003).

Carfentrazone, however, was less effective against *Lathyrus aphaca*, *Ageratum conyzoides* and *Euphorbia heliscopia*, but was very effective against *Convolvulus arvensis* in the Canada thistle infested plots (data not presented). On the other hand, glyphosate was less effective against *C. arvensis* and treated plants regenerated quickly. Differential activity of glyphosate against *C. arvensis* and *Chenopodium album* has been reported (DeGennaro and Weller, 1984; Westhoven *et al*., 2008). Tank mix application of glyphosate with carfentrazone increased the efficacy of mixture against these broad leaf weeds present in Canada thistle treated plots (data not shown). Ilango (2003) observed poor control of *A. conyzoides, Bidens pilosa, Chromolaena odorata, Lantana camara* and other tea weeds by carfentrazone (4 to 20 g/ha) , whereas glyphosate alone (620-720 g/ha) provided only 80-85% control of these weeds. Tank mix application of carfentrazone (12 to 20 g/ha) with glyphosate (620 and 720 g/ha) provided total control of these weeds. Lowering the rate of carfentrazone with glyphosate was also not effective against these major weeds of tea gardens. In the present study with Canada thistle 20 g/ha of carfentrazone with glyphosate (0.75 to 1.5%) provided satisfactory control of Canada thistle and the effect was visible faster than alone application of glyphosate (Fig. 1). The efficacy of the mixture was further enhanced by addition of 2,4-D amine to carfentrazone and glyphosate (Fig. 2). Rajkhowa *et al*. (2005) reported that glyphosate alone provided 48% control of *Borreria articularis*, but tank mix application of glyphosate with carfentrazone and glyphosate+2,4-D+carfentrazone recorded highest control without any phytotoxicity to tea plants. Rajkhowa and Barua (2006) achieved similar control of uncultivated weeds by tank mix of carfentrazone 10 g/ha + glyphosate 600 g/ha to that of glyphosate alone at 1.0 kg/ha. Carfentrazone toxicity symptoms were quick to generate in the treated weed species (*C. arvense* and *C. arvensis*), whereas glyphosate took longer to exhibit mortality symptoms, in the present study. Carfentrazone 20 g/ha provided good control of *C. arvensis*, whereas glyphosate treated plants recovered 4 WAT, but tank mix application improved control and no regeneration was observed 8 WAT (data not shown). Tank mix application of carfentrazone with glyphosate might have an effect on increased uptake and translocation of glyphosate in the treated plants thus improving the efficacy of the mixture. Increased control of Canada thistle in the second year may be due to less number of rooted plants compared to the first year. As the seed bank may be enormous for the germination of new plants after three weeks of herbicide application; their number significantly dwindled in the second year.

Metsulfuron or 2,4-D applied alone or in tank mix application were not effective against Canada thistle in the present study. Reduced density of Canada thistle with metsulfuron or 2,4-D in wheat 60 DAT reported by Yaduraju and Das (2002) could be due to crop suppression in treated plots. Tribenuron failed to control Canada thistle when used alone, as tank mix partner with carfentrazone, metsulfuron or 2,4-D (Fig. 3). Its alone application at 25 g/ha was also not effective against *C. arvensis* (data not presented). Lower efficacy of tribenuron on some broadleaf weeds was also reported earlier (Singh *et al*., 2008). Tribenuron at 10 g/ha+NIS was less effective in reducing shoot density and root biomass of Canada thistle compared to tank mix application of chlorsulfuron at 30 g/ha+NIS and a mixture of clopyralid+2,4-D at 70+280 g/ha (Donald, 1992).

Increased efficacy of tank mix application has been reported for several herbicides and weed species. Mesotrione applied alone did not adequately control Canada thistle, but a mixture of mesotrione 105 g/ha+atrazine 280 g/ha improved control of Canada thistle over mesotrione alone (Armel *et al*., 2005). The control of Canada thistle was 97% with clopyralid 280 g/ha 8 WAT compared to 89% when mesotrione 105 g/ha was tank mixed with clopyralid 140 g/ha, whereas 81% was recorded when 2,4-D was tank mixed with dicamba (140+280 g/ha). Gupta *et al*. (1987) reported that GR_{50} of Canada thistle was lowered by 2.6 and 2.2 times with tank mix applications of 2,4-D+ dicamba than their alone applications, respectively.

Herbicide effect is enhanced when crop plants smother the herbicide suppressed/dying weed species, but this may not always be possible under non-cropped situations. Hoeft *et al*. (2001) evaluated cultural and biological method to control Canada thistle using highly weed-competitive soybean variety and phytopathogenic bacterium (*Pseudomonas syringae* pv. *tagetis*) under conservation tillage. No significant role of variety was found, though the system reduced plant growth and seed production of Canada thistle, but maximum control was recorded with bentazon herbicide.

The present studies exhibit synergistic effect of tank mix applications of glyphosate with carfentrazone and/or with 2,4-D for the control of Canada thistle under non-cropped situations; however, the synergistic effect was not observed for tank mixing of selective wheat herbicides viz., 2,4-D, metsulfuron, tribenuron and carfentrazone among themselves. The effect of tank mix applications of carfentrazone+glyphosate was rapid and provided similar control to that of 2-2.7 time higher rate of glyphosate when used alone. Tank mixing of metsulfuron 4 g with 1.0% glyphosate had similar effect to that of alone applications of glyphosate at 1.0%, but provided lower mortality of Canada thistle than 2.0% glyphosate. Thus, tank mix application of carfentrazone with glyphosate can effectively be used with lower rates of glyphosate without compromising control of Canada thistle.

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