Indian J. Weed Sci. **43** (1 & 2) : 12-22 (2011)

Evaluation of Carfentrazone-ethyl+Metsulfuron-methyl against Broadleaf Weeds of Wheat

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ABSTRACT

Several broadleaf herbicides are available for weed control in wheat, but alone they are not effective against all infesting weeds. Tank mixture often results in antagonism or crop injury, thus reducing crop yield. Field experiments were conducted at CCS Haryana Agricultural University during 2009-10 and 2010-11 to evaluate the efficacy of premix of carfentrazone-ethyl+metsulfuron-methyl (17.5 to 50 g/ha) with and without surfactant and compared with alone application of carfentrazone (20 g/ha), metsulfuron (4 g/ha) and 2,4-D amine (500 g/ha) along with weedy check treatment. Premix of carfentrazone+metsulfuron at 25 g/ha+0.2% surfactant provided effective control of *Malva parviflora, Lathyrus aphaca, Convolvulus arvensis, Rumex dentatus, Melilotus indica, Medicago denticulata, Anagallis arvensis, Coronopus didymus* and *Chenopodium album* which were not effectively controlled by alone application of these herbicides. A non-ionic surfactant (NIS) was essential to increase the efficacy of carfentrazone+metsulfuron mixture. Premix of carfentrazone+metsulfuron 25 g/ha with 0.2% NIS reduced the population of weeds by 97-99% during 2009-10 and 2010-11, respectively, provided 95% control of infested weeds, reducing their dry weight by 98-99%, increasing tiller numbers by 26%, biological yield by 28% and grain yield of wheat by 31% over untreated control. Crop injury (5-15%) by the application of carfentrazone+metsulfuron with 0.2% NIS or carfentrazone alone was transient and caused no reduction in crop yield. The premix of carfentrazone+metsulfuron 25 g/ha+0.2% NIS had similar level of control to its higher rates of 30 and 50 g/ha, but was significantly better than alone application of 2,4-D, metsulfuron or carfentrazone. In another field study, where *Fumaria parviflora* and *Rumex spinosus* were dominant weeds, tank mix of carfentrazone+metsulfuron 20+4 g with 0.2% NIS provided good control than their alone applications in a wheat field during 2009-10. The effect of tank mix application of carfentrazone+metsulfuron at 20+4 g/ha was similar to 600 g/ha of 2,4-D amine and ester, but better than lower rates of 2,4-D formulations. None of the 2,4-D formulations was effective against *R. spinosus*, whereas metsulfuron, carfentrazone and their tank mix provided 85, 78 and 92% control of *R. spinosus*, respectively, and produced 41% higher tillers of wheat over untreated check. Similarly, tank mix of carfentrazone+metsulfuron 20+4 g/ha provided good control of *F. parviflora* in a fallow field during 2010-11. Alone application of carfentrazone or metsulfuron was not effective though plants treated with carfentrazone+metsulfuron recovered later on, but at later stages crop can smother it and the effect of tank mixture was similar to 600 g/ha of 2,4-D ester, but better than its amine formulation and lower rates of 2, 4-D against this weed.

Key words : Herbicide mixture, herbicide synergy, surfactant

INTRODUCTION

Weeds are one of the major constraints in achieving potential yield of wheat. The losses caused by weeds vary depending on the weed species, their density and environmental factors. Because of higher economic cost of labour for manual weeding and its lower efficacy, farmers are relying heavily on herbicides for effective weed control in different crops including wheat. Several grassy and broadleaf weeds infest wheat (Singh *et al*., 1995) causing severe competition for essential nutrients, moisture and space thus reducing wheat yield and also its quality significantly. As wheat fields are infested with diverse weed flora and for their effective management, combination of herbicides either as ready mixture, if compatible (sulfosulfuron+metsulfuron; mesosulfuron+ iodosulfuron) or tank mixture of fenoxaprop-P-ethyl and clodinafop-propargyl with metribuzin (Singh *et al*., 2005); sulfosulfuron and fenoxaprop with carfentrazone (Yadav *et al*., 2009a, b), pinoxaden with carfentrazone

(Singh *et al*., 2010) or as sequential, if not compatible (fenoxaprop or clodinafop with metsulfuron or 2, 4-D) are required. However, the sole dependence on herbicide of single mode of action is also not advisable as it has contributed to shift towards difficult-to-control weeds and the rapid evolution of multiple herbicide resistance, which is a threat to wheat production (Malik and Singh, 1995; Singh, 2007). The benefits and consequences of herbicides mixtures are apparent and should be adhered to while recommending a mixture of more than one herbicide (Wrubel and Gressel, 1994). As the introduction of herbicides with new mode of action has slowed down, therefore, there is need to use mixture of existing herbicides in a way to lower the load on environment and improve weed control efficacy without any adverse effect on crop. Also the cost of application is increased in sequential application and efforts should be made to use a suitable combination of more than one herbicide to combat noxious weeds like *Phalaris minor* along with broadleaf weeds by lowering the cost of herbicide without losing weed control efficacy.

Carfentrazone-ethyl, a post-emergence contact herbicide which kills weeds by desiccation of leaves, has no soil residual activity (half life of 2-5 days), is immobile in soil, requires 1 h to become rainfast and is compatible with many herbicides for effective control of several weeds when applied at early growth stage of weeds (Chopra and Chopra, 2005; Lyon *et al*., 2007; Willis *et al*., 2007; Singh, 2009; Yadav *et al*., 2009a, b; Singh *et al*., 2010; Walia *et al*., 2010). Carfentrazone may cause temporary injury to wheat/barley by cosmetic speckling on leaves, but treated plants recover within 2-3 weeks without any reduction in yield (Howatt, 2005). Though not all herbicides may be compatible with carfentrazone as injury to wheat was more when it was tank mixed with tralkoxydim compared to its alone application or tank mixed with fenoxaprop or clodinafop due to the presence of a safener. Tank mix application of carfentrazone with 2,4-D was found antagonistic against some broadleaf weeds, but not with tribenuron (Singh *et al*., 2008). Carfentrazone injury to crop can be lowered by adding a safener or mixing with sulfonylurea herbicides (Howatt, 2005).

Broadleaf weeds viz., *Malva parviflora* and *Convolvulus arvensis* are not effectively controlled by 2,4-D or metsulfuron, but carfentrazone is very effective against these weed species (Singh *et al*., 2004; Punia *et al*., 2006). On the other hand, efficacy of carfentrazone is lower on several broadleaf weeds compared to metsulfuron particularly under late application stage. Efficacy of carfentrazone or metsulfuron on weeds like *Lathyrus aphaca*, *Fumaria parviflora* and *Coronopus didymus* is unsatisfactory when applied alone, but a combination of both would be ideal for increased spectrum of weed control (Singh *et al*., 2008) without any adverse effect on crop or environment. *F. parviflora* and *Rumex spinosus* are becoming major weeds in light soils of Haryana, Punjab and Rajasthan in the cotton belt of North India in the absence of a suitable herbicide against broadleaf weeds. Metsulfuron or carfentrazone are not effective against *F. parviflora*. 2,4-D is effective against *F. parviflora*, but not against *R. spinosus* and is not preferred by farmers for its sensitivity to some wheat varieties (Pinthus and Natowitz, 1967; Bhan *et al*., 1976) and fear of its causing malformation in cotton when planted after wheat. The present experiment was conducted to evaluate a ready mixture of metsulfuron-methyl 10% and carfentrazone 40% (Ally Express 50% DF) against several broadleaf weeds in wheat and tank mix of carfentrazone 40% DF and metsulfuron 20% WG compared to 2,4-D against *F. parviflora* and *R. spinosus.*

MATERIALS AND METHODS

Wheat cv. PBW 502 was planted on November 07 and 14, respectively, during 2009 and 2010 at a row spacing of 20 cm using 100 kg seed rate/ha. A recommended dose of fertilizer (120 kg N, 60 kg P_2O_5 and 25 kg $ZnSO_4$/ha) was applied at sowing (except nitrogen which was applied in two splits after first and second irrigations). The field was infested with natural weed flora dominated by *Chenopodium album* L., *Melilotus indica* (L.) All., *Medicago denticulata* Willd., *Rumex dentatus* L., *Anagallis arvensis* L., *Lathyrus aphaca* L., *Coronopus didymus* (L.) Sm., *Convolvulus arvensis* L., *Malva parviflora* L. and *Phalaris minor* Retz. (Table 1). Other weeds infesting the field were *F. parviflora* Lam., *C. arvensis* L., *Sonchus arvensis* L., *Avena ludoviciana* Durieu. and *Vicia sativa* L., but not uniformly in all plots. First irrigation was applied at CRI stage and herbicides were applied at 43 (2009-10) and 33 (2010-11) days after sowing (DAS) using premix of carfentrazone-ethyl 40%+metsulfuron-methyl 10% (Ally Express 50% DF) at 17.5, 22.5, 25, 30 and 50 g/ha with and without a non-ionic surfactant at 0.2% and compared with 2,4-D amine 500 g/ha, metsulfuron 4 g/ha and carfentrazone 20 g/ha along with a weedy check in a plot size of 10 x 4.5 m (2009-10) and 5.5 x 3.4 m (2010-11), respectively, with three replications in a randomized block design. Herbicides were sprayed on December 22, 2009 and December 19, 2010 with a backpack sprayer fitted with flat fan multiple nozzle boom delivering 375 l/ha water volume. Grassy weeds (*P. minor* and *A. ludoviciana*) were controlled by spraying grass only herbicides, clodinafop-propargyl 60 g/ha (2009-10) and pinoxaden 50 g/ha (2010-11), respectively. The grassy herbicides were applied a week after spraying of broadleaf herbicides. Both of these herbicides had no adverse effect on any of the broadleaf weeds infesting the trial field. Full package of practices recommended by CCSHAU, Hisar for raising wheat crop was followed. Observations were recorded for weed population before and after spraying using a quadrant of 0.5 x 0.5 m, crop injury and per cent weed control (on 0-100 scale, where, 0=no effect and 100=complete mortality), weed dry weight (10, 50 and 120 DAS), tillers/running metre length, biological and grain yield of wheat at harvest. Data from two years were pooled (similar trend) and subjected to ANOVA using SPSS for statistical analysis.

In the second study conducted at farmer's field during 2009-10 which was highly infested with *F. parviflora* and *Rumex dentatus* L. and in a fallow field at CCSHAU, Hisar during 2010-11 with huge population of *F. parviflora*, tank mix of carfentrazone 40% DF (Affinity) and metsulfuron 20% WP/WG (Algrip) at 20+4 g/ha were compared with their alone applications and 2,4-D amine 58% SL (50% a.e.) (Weedkil) at 400 and 600 g/ha and Ester 38% EC (34% a. e.) (Weednash) at 320, 400 and 600 g/ha along with a weedy check treatment (Fig. 1). Wheat field planted on December 04, 2009 in Dharnia village (Fatehabad district) with 200-300 plants/m^2 of *F. parviflora* was sprayed 40 DAS on January 14, 2010 in a plot size of 10 x 16 m with three replications. *F. parviflora* was at 10-20 cm height and the taller plants were in flowering stage at the time of spray. *R. spinosus* was the other major weed infesting the field. Visual mortality was recorded 10, 28 and 65 days after treatment (DAT) and wheat plant growth (plant height and tiller number per running meter) was recorded 105 DAS. The same eight-treatment trial (described above) was repeated in a fallow field at Agronomy Research Farm of CCSHAU, Hisar with heavy infestation of *F. parviflora*. Herbicides were sprayed on January 18, 2011 in a plot size of 4 x 20 m, replicated thrice. A NIS at 0.2% was used in all treatments with metsulfuron or its tank mix applications with carfentrazone. At the time of spray *F. parviflora* plants were 15-20 in height, well branched and at flower initiation stage. Other major weeds present in the field were *Chenopodium album, Convolvulus arvensis* and *Cirsium arvense* (15%). Observations were recorded on visual mortality after 2, 4, 7, 14, 21, 28 and 65 days after spray. Plant population and fresh weight were recorded 28 and 65 DAT using a quadrant of 0.5 x 0.5 m. Data of both experiments were analyzed separately using SPSS.

RESULTS AND DISCUSSION

Weed Population and their Dry Matter Accumulation

C. album was the most dominant weed during both the years followed by *R. dentatus, M. denticulata, M. indica* and *A. arvensis* (Table 1). All the major weeds were uniformly distributed in the plots when recorded before spray. *C. didymus*, *F. parviflora, V. sativa* and *S. arvensis* were more prevalent during the first year, whereas *C. arvensis* was more during the second year, though overall weed intensity was lower in the second compared to the first year.

Premix formulation of carfentrazone+ metsulfuron (Ally Express) 25 g/ha+0.2% non-ionic surfactant (NIS) provided effective control of *A. arvensis, C. album, M. parviflora, M. denticulata, M. indica*, *R. dentatus* and *L. aphaca* as observed 50 and 120 DAT (Table 2), reducing the total population of weeds by 97 and 99%, respectively, compared to untreated control plots. Premix of carfentrazone+ metsulfuron 25 g/ha+0.2% NIS was very effective against *F. parviflora* and *C. didymus*, though emergence of new flush was observed later on, but that was not significant (data not shown). Increasing the dose to 30 or 50 g/ha, though reduced the total number of weeds, but had no significant increase in weed control efficiency over 25 g/ha which was better than lower rates of 17.5 and 22.5 g/ha with 0.2% NIS. Effect of premix of carfentrazone+metsulfuron was lower without surfactant and required higher rates (50 g/ha) to achieve the same level of control to that of lower rate (25 g/ha) with surfactant. Premix of carfentrazone+metsulfuron at 25 g/ha+0.2% NIS was better than alone applications of metsulfuron 4 g/ha, carfentrazone 20 g/ha or 2,4-D amine

Table 1. Weed population in wheat field at the time of spray (mean of two years)

Herbicides	Weed population (No./m^2)							
	Anagallis arvensis	*Chenopodium album*	*Lathyrus aphaca*	*Malva parviflora*	*Medicago denticulata*	*Melilotus indica*	*Rumex dentatus*	Total weeds
CZN+MSM 17.5 g+NIS	23	45	15	7	23	21	27	172
CZN+MSM 22.5 g+NIS	25	48	15	7	21	16	30	174
CZN+MSM 25 g+NIS	19	48	10	6	24	20	36	174
CZN+MSM 30 g+NIS	23	46	17	9	21	16	37	177
CZN+MSM 50 g+NIS	27	47	13	8	26	19	37	183
2,4-D amine 500 g	27	42	15	8	25	19	41	189
CZN+MSM 17.5 g	27	46	16	7	27	17	43	196
CZN+MSM 22.5 g	23	45	13	11	24	23	31	179
CZN+MSM 25 g	19	49	17	9	25	21	37	192
CZN+MSM 30 g	24	51	16	9	25	19	35	191
CZN+MSM 50 g	21	51	15	8	29	20	44	195
MSM 4 g	19	56	14	7	26	16	46	191
CZN 20 g	15	49	19	7	23	19	45	187
Weedy check	25	49	13	10	25	24	35	189
S. Em	5.4	6.49	3.7	2.2	4.4	4.8	8.3	14.55
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

CZN–Carfentrazone-ethyl, MSM–Metsulfuron-methyl, NIS–Non-ionic surfactant. NS–Not Significant.

500 g/ha on target weed species. Weed population was higher with 500 g/ha 2,4-D amine treated plots as it could not provide effective control of *L. aphaca*, *M. parviflora* and *R. dentatus*, also effect was lower on other broadleaf weeds due to advanced growth stage of weeds at the time of spray in the first year (Table 2). Similarly, metsulfuron 4 g/ha was less effective on *L. aphaca* and *M. parviflora*; though both metsulfuron and 2,4-D suppressed these weed species. *A. arvensis* plants treated with carfentrazone 20 g/ha had some recovery and taller plants of *C. album*, *M. indica* and *M. denticulata* were not completely killed resulting in their higher population compared to premix of carfentrazone+metsulfuron at 25 g/ha +0.2% NIS (Table 2).

At 120 DAT (Table 2), the number of weeds was lower under different treatments compared to 50 DAT which may be due to increased mortality as some weeds were not completely killed by herbicidal treatments earlier or intraspecific competition; however, the trend of herbicide treatments was similar.

Dry matter accumulation by weeds decreased with increase in the application rates of carfentrazone+ metsulfuron with or without surfactant (Table 2). Lowest weed dry weight was recorded with 50 g/ha of carfentrazone+metsulfuron+0.2% surfactant which was statistically similar to its 25 g/ha rate during both the stages of observation. Role of surfactant was evident as its addition to carfentrazone+metsulfuron resulted in significantly lower dry matter accumulation by weeds compared to its absence in the mixture. Without surfactant even double the rate of carfentrazone+ metsulfuron (50 g/ha) could not reduce dry weight of weeds to the level of its 50% lower rate (25 g/ha) with surfactant. Reduction in dry matter accumulation by weeds in 2,4-D 500 g/ha, carfentrazone 20 g/ha and metsulfuron 4 g/ha treated plots was 79 and 84%, 80 and 90%, and 82 and 91% at 50 and 120 DAT, respectively, over weedy plots compared to 98 and 99% under 25 g/ha carfentrazone+metsulfuron (Table 2). This was due to higher occurrence of *L. aphaca* and *M. parviflora* in 2,4-D 500 g and metsulfuron 4 g/ha treated plots, and *C. album*, *M. indica*, *M. denticulata* and *A. arvensis* in carfentrazone 20 g/ha treated plots compared to premix of 25 g/ha of carfentrazone+metsulfuron mixed with 0.2% NIS.

Crop Phytotoxicity and Weed Mortality

There was no adverse effect of premix of carfentrazone+metsulfuron on wheat crop during both the years. Crop leaf injury of 5 to 15% was observed

Table 2. Effect of premix of carfentrazone and metsulfuron on weed population and their dry matter accumulation (mean of two years)

Herbicides	Weed population (No./m^2) 50 and 120 DAT																	
	Anagallis arvensis		*Chenopodium album*		*Lathyrus aphaca*		*Malva parviflora*		*Medicago denticulata*		*Melilotus indica*		*Rumex dentatus*		Total weeds		Weeds dry weight (g/m^2)	
	50	120	50	120	50	120	50	120	50	120	50	120	50	120	50	120	50	120
CZN+MSM 17.5 g+NIS	12	5	6	3	9	7	3	2	8	2	5	3	11	3	61	28	56.7	68.3
CZN+MSM 22.5 g+NIS	10	1	1	1	7	2	1	0	1	0	0	5	3	1	26	12	27.5	30.7
CZN+MSM 25 g+NIS	2	1	0	1	1	0	0	0	0	0	0	0	1	0	7	2	5.0	1.3
CZN+MSM 30 g+NIS	1	1	0	1	0	0	0	0	0	0	0	0	1	0	3	1	2.2	2.3
CZN+MSM 50 g+NIS	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0.0	2.0
2,4-D amine 500 g	5	5	4	2	15	8	7	7	8	6	2	6	11	13	63	47	47.2	103.3
CZN+MSM 17.5 g	15	5	11	5	11	12	7	8	4	3	7	7	14	3	80	52	72.5	89.8
CZN+MSM 22.5 g	8	6	4	3	10	7	3	3	3	3	4	4	5	3	47	33	49.3	56.8
CZN+MSM 25 g	4	2	3	1	5	5	3	0	0	1	0	2	5	0	24	13	21.7	50.2
CZN+MSM 30 g	1	1	2	1	3	3	0	0	1	1	0	2	2	0	13	8	8.5	31.2
CZN+MSM 50 g	0	1	0	0	1	2	0	0	0	0	0	2	0	0	3	5	2.7	16.7
MSM 4 g	4	3	3	1	7	7	5	8	8	1	1	3	7	1	46	27	39.2	54.8
CZN 20 g	15	7	7	7	9	5	1	0	6	3	5	5	5	2	53	32	43.7	64.2
Weedy check	29	15	44	35	30	18	15	13	35	13	26	14	34	25	239	141	224.2	632.5
LSD (P=0.05)	3	3	3	4	4	3	3	2	3	3	3	4	3	4	6	5	6.0	7.47

CZN–Carfentrazone-ethyl, MSM–Metsulfuron-methyl, NIS–Non-ionic surfactant.

10 DAT in plots treated with carfentrazone+metsulfuron or carfentrazone alone, but not at later stages (data not included). Some necrotic spots were observed on wheat leaves, but they disappeared within a fortnight without adversely affecting crop growth.

Weed mortality increased with increasing rates of premix of carfentrazone+metsulfuron from 17.5 to 50 g/ha; effect was more when used with surfactant as recorded 10 DAT (Table 3). Lower weed mortality was recorded with 2,4-D amine, metsulfuron and carfentrazone 10 DAT compared to carfentrazone+ metsulfuron tank mixed with surfactant. At 50 DAT, higher weed mortality of 88-98% was observed for all herbicide treatments, but the differences were apparent at 75 and 120 DAT. Premix of carfentrazone+ metsulfuron 25 g/ha+0.25% NIS provided 95% control of weeds which was significantly better than its lower rates and was comparable to higher rates when used with or without surfactant (Table 3). Also premix of carfentrazone+metsulfuron 25 g/ha+0.2% NIS was significantly better than alone application of 2,4-D amine 500 g/ha, carfentrazone 20 g/ha or metsulfuron 4 g/ha when observed 75 or 120 DAT.

Yield Attributes and Yield of Wheat

Premix of carfentrazone+metsulfuron 25 g/ha with 0.2% NIS resulted in effective weed control thereby producing 25% higher tillers per metre row length recorded at harvest compared to weedy plots (Table 3). These tillers were significantly more than its lower rate of 17.5 g+0.2% NIS or higher rates without surfactant and other herbicides *viz.,* 2,4-D amine, metsulfuron or carfentrazone. Increasing the rates of carfentrazone+ metsulfuron+0.2% NIS had no increase in the number of tillers over 25 g/ha rate with 0.2% NIS.

Similar trends were observed for biological yield where premix of 25 g/ha of carfentrazone+metsulfuron with 0.2% NIS provided 28% higher biological yield over weedy check. Highest grain yield of wheat (4966 kg/ha) was recorded with premix of carfentrazone+ metsulfuron at 25 g/ha rate tank mixed with 0.2% NIS which was 31% higher over untreated weedy plots (Table 3). There was no significant difference in the yield of wheat treated with carfentrazone+metsulfuron+0.25% NIS from 22.5 to 50 g/ha rate, but it was significantly higher than lower rates of 17.5 g with surfactant. Premix of carfentrazone+metsulfuron at 25 g/ha+0.2% NIS provided higher but statistically similar yield to its higher rates of 30 and 50 g/ha without surfactant and metsulfuron, but significantly higher yield than carfentrazone alone or 2,4-D amine 500 g/ha.

Tank Mixture of Carfentrazone+Metsulfuron and 2,4-D Formulations

Effect on weeds and wheat crop (2009-10) : At 10 DAT, tank mixture of carfentrazone + metsulfuron at 20+4 g/ha provided 92% control of *F. parviflora* compared to 48 and 20% control by carfentrazone 20 g/ha and metsulfuron 4 g/ha alone, respectively (Fig. 1). 2,4-D ester was more effective than its amine salt, but there was no significant difference between 400 and 600 g/ha application rates, 10 DAT. Efficacy of amine salt and lower rate of ester formulation of 2,4-D slightly increased 28 DAT, but it decreased by 10% in plots treated with tank mixture of carfentrazone+metsulfuron. Slight decrease was also observed in plots treated with higher rates of 2,4-D ester at 28 compared to 10 DAT (Fig. 1). *F. parviflora* plants which started regenerating 28 DAT further lowered the control in all the herbicidal treatments, though tank mix of carfentrazone+ metsulfuron 20+4 g still recorded 73% control which was statistically similar to 600 and 400 g/ha of 2,4-D ester, but better than its lower rates or amine formulation at both used rates. Plants of *F. parviflora* exhibited only 12-13% suppression compared to untreated control, 65 DAT. 2,4-D ester 600 g/ha provided only 60% control of *R. spinosus* observed 65 DAT, whereas its lower rates or amine formulations were less effective, but carfentrazone, metsulfuron and their tank mixture provided 78, 85 and 92% control, respectively (Fig. 1). Plant height of wheat was not affected 65 DAT (data not shown), but significant effect on tillers of wheat was observed for different weed control treatments. Tank mixture of carfentrazone+metsulfuron 20+4 g+0.2% NIS resulted in maximum (74) tillers per metre row followed by 2,4-D ester 600 g (71); all other treatments had significantly lower tillers.

Effect on *F. parviflora* (2010-11) : Carfentrazone and 2,4-D formulations inflicted 25-28% injury to *F. parviflora* within 48 h compared to only 10% by metsulfuron, whereas tank mix application of carfentrazone+metsulfuron resulted in 45% injury which increased to 68 and 83% after 5 and 9 days, respectively (Fig. 2). Effect of 2,4-D formulations increased from 33 to 62% and 42 to 72% after 7 and 14 DAT,

Table 3. Effect of premix of carfentrazone and metsulfuron on weed mortality, yield attributes and yield of wheat (mean of two years)

Herbicides	Weed mortality (%)				Yield attributes of wheat		
	10 DAT	50 DAT	75 DAT	120 DAT	Tillers/mrl	Biological yield (q/ha)	Grain yield (q/ha)
CZN+MSM 17.5 g+NIS	74	92	77	77	124	108	44.33
CZN+MSM 22.5 g+NIS	79	98	80	80	129	113	47.45
CZN+MSM 25 g+NIS	86	98	95	95	134	120	49.66
CZN+MSM 30 g+NIS	84	98	93	93	134	118	49.18
CZN+MSM 50 g+NIS	90	100	96	96	133	119	49.53
2,4-D amine 500 g	76	92	80	80	124	110	44.76
CZN+MSM 17.5 g	64	88	67	67	117	102	40.42
CZN+MSM 22.5 g	68	88	73	73	120	106	43.13
CZN+MSM 25 g	80	93	85	85	120	109	43.96
CZN+MSM 30 g	83	90	87	87	126	109	45.74
CZN+MSM 50 g	84	98	87	87	125	113	47.03
MSM 4 g	73	92	85	87	129	115	45.25
CZN 20 g	79	93	78	78	128	114	44.93
Weedy check	0	0	0	0	99	87	34.15
LSD (P=0.05)	5	4	5	5	4	33	4.42

CZN–Carfentrazone-ethyl, MSM–Metsulfuron-methyl, NIS–Non-ionic surfactant.

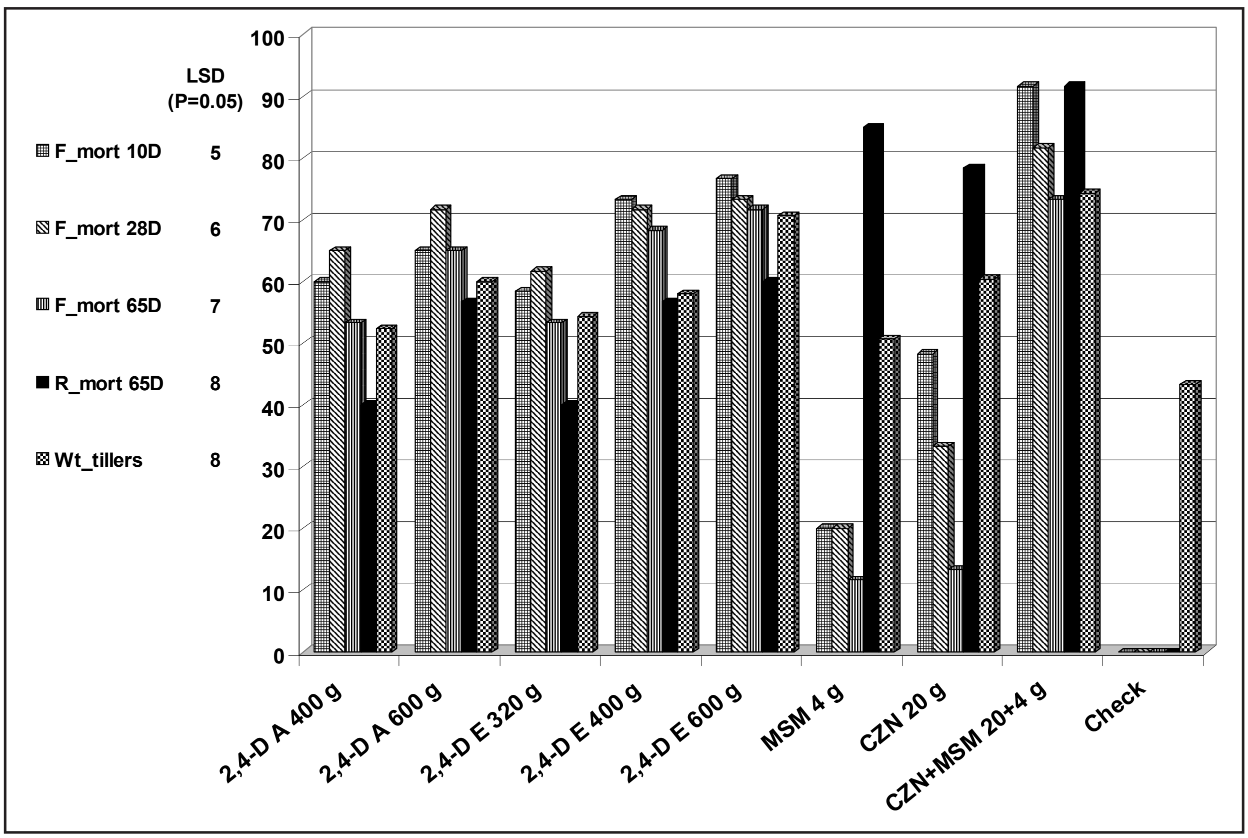

Fig. 1. Effect of different herbicide treatments on the mortality of *F. parviflora* (F_mort) and *R. spinosus* (R_mort) and tillers of wheat (Wt_tillers), 2,4-D A–2,4-D amine, 2,4-D E–2,4-D ester, MSM–Metsulfuron-methyl and CZN–Carfentrazone-ethyl.