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Interaction Effect of Water Temperature for Spraying Clodinafop Formulations on *Phalaris minor* biotypes

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ABSTRACT

Pot studies were carried out at CCS Haryana Agricultural University, Hisar during 2006-07 and 2007-08 to evaluate the effect of water temperature for spraying clodinafop-propargyl formulations on several biotypes of *P. minor* and response to alternate herbicides. Clodinafop formulations (Topik, Point, Rakshak Plus, Moolah and Jai-Vijay) at 60 g/ha were sprayed using water at temperatures of 8, 25 and 40^{O}C on *P. minor* biotypes J-35, KUL, F-42, B-6, H-2, Bajekan during 2006-07 and Garhi Birbal, Jyotisar, Sarwan, Nangla, Jat and Lalodha during 2007-08. Isoproturon 1.5 kg/ha, chlorotoluron 1.0 kg/ha, premix of sulfosulfuron+metsulfuron (Total) 32 g/ha, mesosulfuron+iodosulfuron (Atlantis) 14.4 g/ha, pinoxaden 45 g/ha, fenoxaprop-P-ethyl 100 g/ha and quizalofop-P-ethyl 100 g/ha were sprayed using normal water temperature (25^{O}C) on *P. minor* biotypes. Chlorotoluron was replaced with clodinafop 90 g during the second year. Mortality of *P. minor* biotypes was significantly decreased with clodinafop formulations when water temperature of 8^{O}C was used for spraying compared to 25 or 40^{O}C temperature water. There was no difference in mortality of *P. minor* biotypes between 25 and 40 ^{O}C temperature water for spraying, eight weeks after treatment (WAT); however, significant differences in dry matter accumulation by *P. minor* biotypes were recorded due to water temperature for spraying clodinafop. Clodinafop formulation, Topik was more effective compared to Jai-Vijay, but differences were non-significant among different formulations. Significant variations in mortality and dry weight were observed among *P. minor* biotypes with different herbicides. Chlorotoluron provided effective control of isoproturon resistant biotypes, which were also susceptible to quizalofop. Lalodha biotype was highly resistant to fenoxaprop, isoproturon and clodinafop and even increased rate of 90 g/ha clodinafop also failed to effectively control this biotype. Pinoxaden, sulfosulfuron+metsulfuron, mesosulfuron+iodosulfuron and quizalofop; however, provided 90-100% control of these resistant biotypes. Variations in mortality by pinoxaden, sulfosulfuron+metsulfuron and mesosulfuron+iodosulfuron herbicides were also observed in some biotypes which need further confirmation.

Key words : Herbicide efficacy, resistance, isoproturon, pinoxaden, fenoxaprop, sulfosulfuron+ metsulfuron, mesosulfuron+iodosulfuron, quizalofop, chlorotoluron

INTRODUCTION

The importance of using clean and clear water for mixing herbicide solutions has been reported to achieve optimum herbicide efficacy (Stahlman and Philips, 1979; Buhler and Burnside, 1983; Holm *et al*., 1994; Singh *et al*., 2004). Water quality as influenced by dissolved ions (calcium, magnesium, sodium, sulphates, chlorides, biocarbonate, potassium, iron and nitrate) which affect the electrical conductivity and even dirt particles can impact the efficacy of several herbicides by increased adsorption of herbicide molecules. Lower efficacy of post-emergence herbicides has been reported due to water hardiness (glyphosate, imazethapyr, sethoxydim and glufosinate), turbidity (clethodim, sethoxydim, paraquat and glyphosate) or higher pH for weak acids like glyphosate, paraquat, sethoxydim and 2,4-D, due to dissolved salts. Water which constitutes 99% of herbicide spray volume also affects the efficacy of several herbicides like fenoxaprop-P-ethyl and clodinafop-propargyl (Gauvrit *et al*. 2003; Andrews *et al*., 2007, 2008; Gauvrit and Lamrani, 2008). Water temperature can also affect some herbicides or their formulations. If the water temperature is too low, the herbicides will form a sludge at the bottom of the spray tank.

Clodinafop is a selective and translocated herbicide for the control of annual grassy weed in wheat that is absorbed through leaves and a safener (cloquintocet) is added to reduce wheat phytotoxicity. The herbicide is more effective when applied at the 2-3 leaf stage of grasses when environmental conditions are conducive. There is paucity of information in the literature on the effect of water temperature used for spraying clodinafop. Some complaints of reduced herbicide efficacy were received from the farmer's field during 2005-06 where the cold water was used for spraying clodinafop in the months of December and January. Lower efficacy of herbicides could also be due to evolution of resistance when the same herbicide is repeatedly used (Malik and Singh, 1995; Singh *et al.*, 1998, 1999). Subsequent to failure of isoproturon, diclofop-methyl was recommended for the management of *P. minor*, but that too exhibited cross-resistance (Kirkwood *et al*., 1997) and the same had to be withdrawn. Poor efficacy of clodinafop, fenoxaprop and sulfosulfuron was also reported from farmers' field after a decade of their use (Yadav *et al*., 2006; Singh, 2006, 2007; Chhokar and Sharma, 2008; Dhawan *et al*., 2009). The present experiment was conducted to investigate the role of water temperature used to spray several formulations of clodinafop against some biotypes of *Phalaris minor* collected from different locations of Haryana state and effect of alternate herbicides.

MATERIALS AND METHODS

Screen house studies were carried out during 2006-07 and 2007-08 at CCS Haryana Agricultural University, Hisar. Field soil from non-experimental area of Agronomy Department was mixed in 2 : 1 : 1 ratio of field soil, dunal sand and vermicompost and filled in plastic pots of 20 cm height and top diameter with 6.5 kg soil capacity. The field soil was sandy loam in texture, low in organic carbon and available N, medium in P_2O_5 and high in K_2O with a pH of 8.3.

Phalaris minor biotypes, J-35 (Jind), Kulvehari (Karnal), F-42 (Fetehabad), B-6 (Bihar) and H-2 (Hisar), collected earlier and raised in the field under earthen pots for seed multiplication during 2005-06 were used in the present study along with seed collected in April 2006 from farmers' field where poor herbicide efficacy was reported (Bajekan, Sirsa). H-2 is susceptible biotype and standard check for comparing herbicide resistance, whereas B-6 is a pristine biotype of *P. minor*. During 2007, seeds were collected from Garhi Birbal (Karnal), Sarwan (Yamunanagar), Jyotisar (Kurukshetra), Lalodha, Jat and Nangla (Fatehabad district) of Haryana. Twenty seeds of each biotype were planted at 1 cm depth and thinning was done one week after emergence to maintain 10 plants per pot for spraying. Spraying was done when plants attained 22-28 cm mean height (different biotypes) during 2007 and 18-24 cm during 2008. Clodinafop-propargyl formulations, Topik (Syngenta), Point (Nagarjuna), Rakshak Plus (Cheminova), Jai-Vijay (Gharda) and Moolah (Crop Health) were sprayed at 60 g/ha using three water temperatures of 8, 25 and 40^{O}C using flat fan nozzle delivering 375 l/ha water volume by a knapsack sprayer. There were three replicated pots for each biotype and treatments. Control pots for each biotype were maintained for comparison. During the first year comparisons were also made with isoproturon 1.5 kg/ha, premix of sulfosulfuron+metsulfuron (Total) 32 g/ha, mesosulfuron+iodosulfuron (Atlantis) 14.4 g, quizalofop-P-ethyl 100 g, fenoxaprop-P-ethyl 100 g/ha, chlorotoluron 1.0 kg/ha and pinoxaden 45 g/ha sprayed with water temperature of 25^{O}C. In the second year chlorotoluron was replaced with clodinafop at 90 g/ha rate. Periodical observations were recorded on weed mortality and dry weight (g/pot) was recorded during the second year. Data from both the years were analyzed separately using SPSS.

RESULTS AND DISCUSSION

Water temperature for spraying significantly affected the mortality of *P. minor* biotypes (Fig. 1). When data were recorded two weeks after treatment (WAT), mean mortality of 40, 53 and 55% was recorded for water temperatures of 8, 25 and 40^{O}C, respectively (averaged over clodinafop formulations and biotypes). Mortality was similar at 40 and 25^{O}C but lower water temperature for spraying adversely affected clodinafop mortality on *P. minor* biotypes. Variations were also observed among clodinafop formulations where Topik resulted in highest mortality of 53% compared to only 45% by Jai-Vijay formulation, data averaged over temperature and biotypes. Other than Jai-Vijay formulation all were non-significant on their effect against *P. minor* biotypes. Similarly, large variations were observed in the mortality of *P. minor* biotypes with clodinafop. *P. minor* biotypes (H-2 and B-6) recorded significantly higher mortality compared to other biotypes, data averaged over temperature and clodinafop formulations.

Chlorotoluron 1.0 kg provided 100% mortality of *P. minor* biotypes followed by pinoxaden 45 g/ha, isoproturon 1.5 kg/ha and quizalofop (77, 73 and 70%, respectively), which was significantly higher than other herbicides (data averaged over biotypes), whereas fenoxaprop was least effective with 47% mortality (Fig. 2). Among the biotypes, H-2 and B-6 were most sensitive, whereas J-35 and KUL biotypes were least to herbicides when data were averaged (Fig. 2). *P. minor* biotypes J-35 and KUL were not effectively controlled by 1.5 X dose of isoproturon and F-42 was intermediate; similarly fenoxaprop was not found effective. Chlorotoluron and quizalofop provided effective kill of all the biotypes.

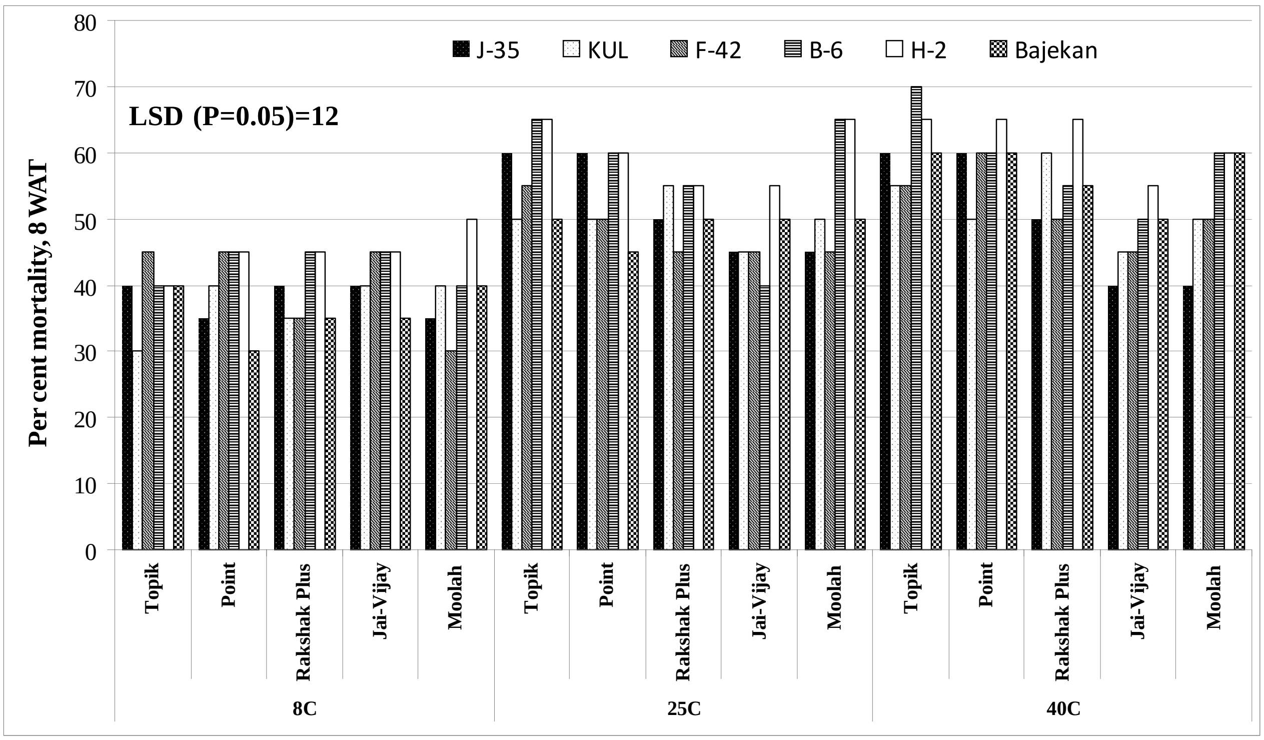

Fig. 1. Effect of water temperature for spraying on *P. minor* biotypes mortality by different clodinafop formulations (2006-07).

Significant differences on the efficacy of clodinafop formulations on different biotypes of *P. minor* were observed during 2007-08. Water temperature of 8^{O}C for spraying clodinafop formulations resulted in 57% mortality compared to 75% with water temperature of 25 or 40^{O}C, data averaged (Fig. 3). There were no differences between 25 and 40^{O}C water temperature on *P. minor* mortality 8 WAT. *P. minor* biotype from Garhi Birbal (89%) was most sensitive to clodinafop formulations followed by Jyotisar (86%) and Sarwan (83%), whereas Lalodha (26%) and Jat (62%) biotypes exhibited lowest mortality, data averaged over temperature and formulations. Differences among clodinafop formulations ranged from 66 to 75%, when data were averaged over biotypes (Fig. 3). Lalodha, Jat and Nangla biotypes defied all clodinafop formulations; increasing the water temperature for spraying clodinafop from 8 to 25^{O}C, though increased mortality of Jat and Nangla biotypes, but this was not significant in the case of Lalodha biotype. Higher mortality of *P. minor* biotypes was observed with Topik formulation of clodinafop, but the differences were not statistically significant among formulations. Higher water temperature (40^{O}C) for spraying exhibited higher mortality soon after spraying but the differences were non-significant between 25 and 40^{O}C, 8 WAT. Rakshak Plus and Jai-Vijay formulations on the other hand resulted in lower mortality in some biotypes of *P. minor* when the water temperature for spraying was increased from 25 to 40^{O}C (Fig. 3).

Dry matter accumulation demonstrated similar effect on mortality when water of different temperatures was used for spraying clodinafop formulations. Dry

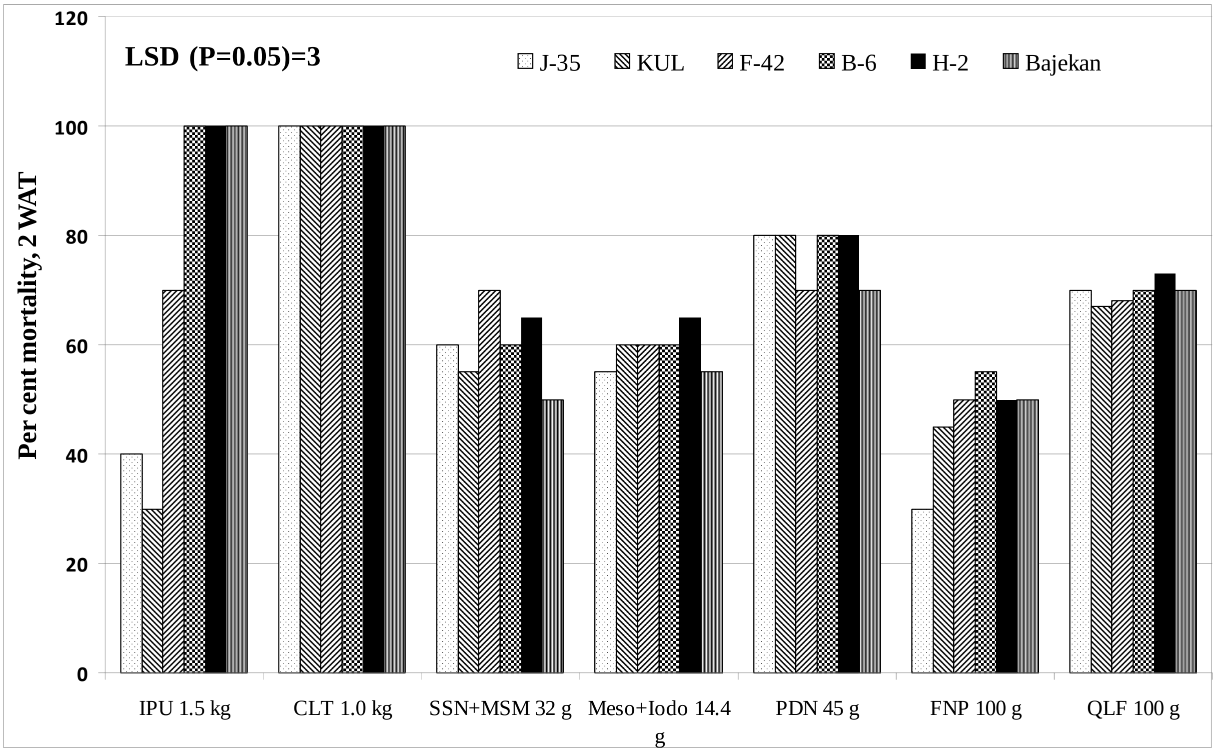

Fig. 2. Effect of different herbicides on *P. minor* biotypes mortality (2006-07). IPU = isoproturon, CLT=chlorotoluron, SSN=sulfosulfuron, MSM=metsulfuron, Meso=mesosulfuron, Iodo=iodosulfuron, FNP=fenoxaprop, PDN=pinoxaden, QLF=quizalofop.

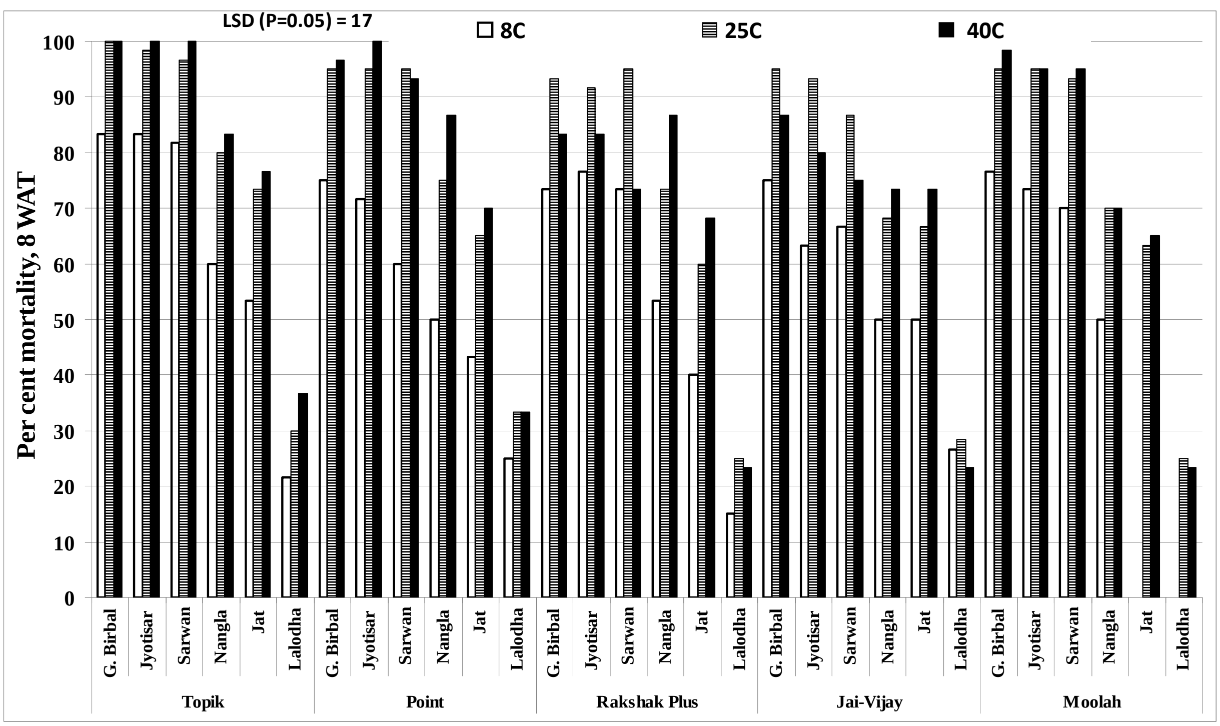

Fig. 3. Effect of water temperature for spraying clodinafop formulations on mortality of different biotypes of *P. minor* during 2007-08.

weight of *P. minor* biotypes at 8^{O}C water temperature for spraying was 2.29 and 1.77 times higher compared to 40 and 25^{O}C water temperature for spraying, data averaged (Fig. 4). Dry matter accumulation was significantly reduced with increase in water temperature for spraying from 8 to 25 and 40^{O}C. Reduction in dry weight of Garhi Birbal, Jyotisar, Sarwan, Nangla, Jat and Lalodha biotypes was 77, 65, 54, 49, 36 and 4%, respectively, over untreated control (Fig. 4). Lowest dry weight of biotypes (averaged) was recorded with Topik and Moolah and highest with Point and Jai-Vijay formulations, though differences were not statistically significant. Dry weight of *P. minor* biotypes under untreated pots did not follow any trend to that of their sensitivity or resistance to clodinafop, though lowest dry weight was in case of Lalodha followed by Jat and Nangla biotypes.

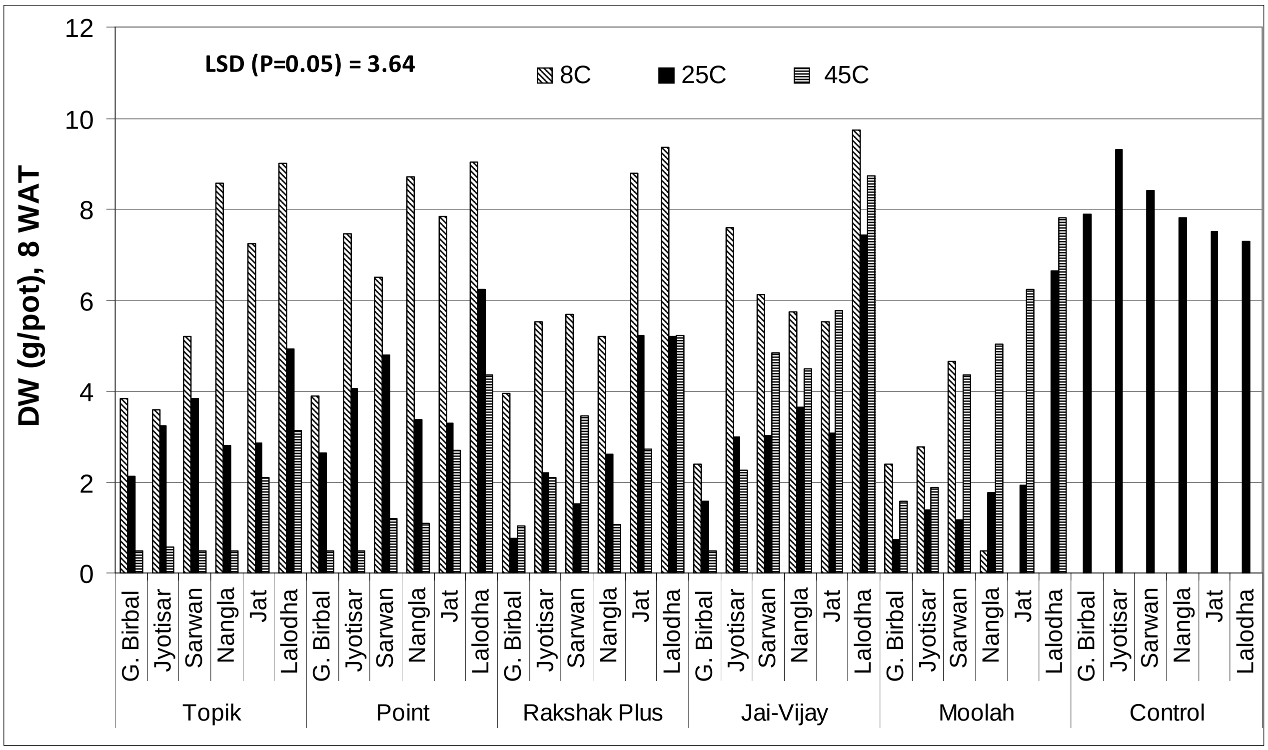

Fig. 4. Effect of water temperature for spraying clodinafop formulations on dry weight of different biotypes of *P. minor* during 2007-08.

Isoproturon 1.0 kg/ha and fenoxaprop 100 g/ha were not effective against any of the test biotypes, whereas 50% higher rates of clodinafop provided poor control of Jat and Lalodha biotypes (Fig. 5). Quizalofop, pinoxaden, mesosulfuron+iodosulfuron and sulfosulfuron+ metsulfuron provided good control, though some variations were observed in the mortality of *P. minor* biotypes with the later ones (Fig. 5). Similar trends were recorded with different herbicides on dry matter accumulation by *P. minor* biotypes (Fig. 6).

Significantly lower mortality of *P. minor* biotypes with clodinafop formulations at 8^{O}C water temperature for spraying compared to 25^{O}C may be due to poor solubility of the wettable powder formulation of clodinafop or its surfactant/additives resulting in poor target site delivery. Netherland *et al*. (2000) reported poor control of aquatic weeds when herbicides were applied at lower water temperature. Though herbicides at all temperatures reduced weed biomass and growth, but effect was more at 25 than 10^{O}C. Olson *et al*. (2000) reported effect of temperature and moisture on the efficacy of Mon 37500. Environmental factors have been reported to affect herbicide efficacy against *P. minor* (Malik and Singh, 1994). Air temperature does not generally affect herbicide efficacy for winter season crops, but lower efficacy in the present study with lower water temperature for spraying may be due to improper herbicide solution. The mortality of *P. minor* biotypes increased with time in 8^{O}C water temperature for spraying clodinafop, but could not make up for normal

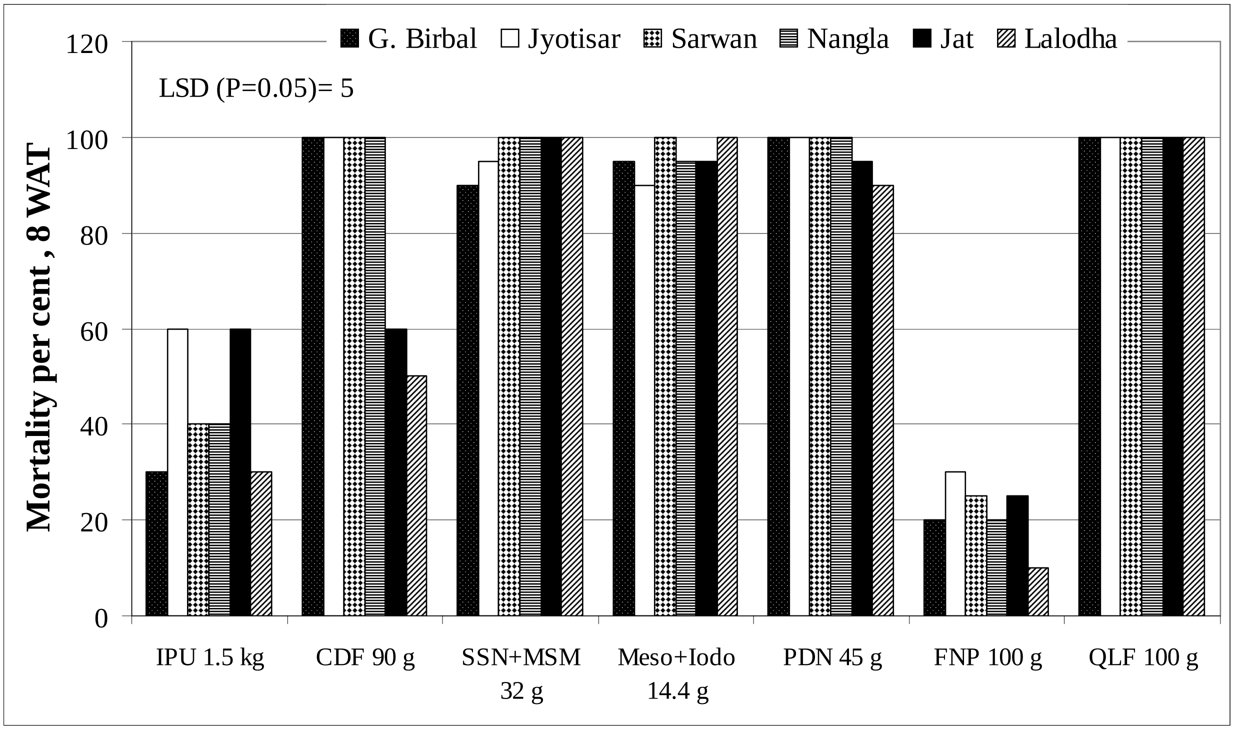

Fig. 5. Effect of different herbicides on the mortality of *P. minor* biotypes (2007-08).

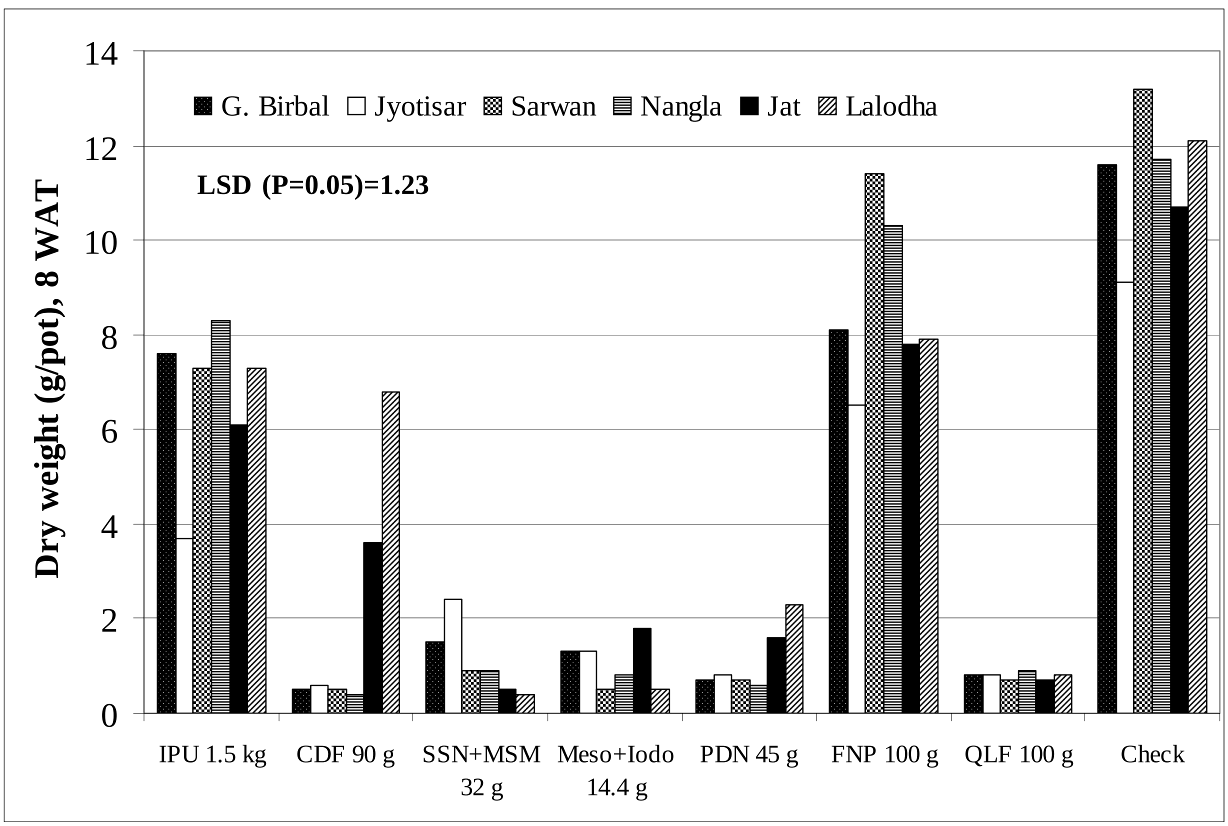

Fig. 6. Effect of different herbicides on dry weight of *P. minor* biotypes (2007-08).

water (25^{O}C) or higher temperature. Water temperature of 40^{O}C for mixing and spraying clodinafop formulations resulted in higher mortality initially, but the effect was similar to normal water temperature (25^{O}C) at 8 WAT. However, the effect was more in dry matter accumulation by *P. minor* biotypes when clodinafop formulations were sprayed with 8 to 40^{O}C water temperature. This might be due to differential morality of *P. minor* at early stage. Variations in the efficacy of clodinafop formulations also may be due to their solubility in water due to different formulating chemicals.

P. minor biotypes J-35 and KUL were resistant to isoproturon, whereas F-42 had both susceptible and resistant plants, but all these biotypes were effectively killed by chlorotoluron (Fig 2). Isoproturon resistant biotypes of *P. minor* have been found to be sensitive to chlorotoluron (Singh *et al*., 1998; Singh, 2006). The efficacy of fenoxaprop was lower on these biotypes compared to clodinafop (Figs. 1 and 2), but the level of resistance was lower compared to Jat, Nangla and Lalodha biotypes (Fig. 5). These results are in conformity with field complaints of poor efficacy of fenoxaprop and clodinafop and reported earlier (Yadav *et al*., 2006; Chhokar and Sharma, 2008; Dhawan *et al*., 2009). The Lalodha biotype was most resistant to all clodinafop formulations and even 50% higher rate of clodinafop failed to control it (Figs. 5 and 6). Increased rate of clodinafop increased mortality of Nangla, Jat and Lalodha biotypes (Figs. 3 and 5) which indicates enhanced detoxification; however, target site alteration has also been reported in some *P. minor* biotypes from India (Kaundun, 2006). Kaundun (2010) reported both target site mutation and non-target site mechanisms conferring resistance to ACCase inhibitor herbicides in *Lolium multiflorum*. Gherekhloo *et al*. (2008, 2009) also reported ACCase mutation in *P. minor* biotypes from Iran conferring resistance to ACCase inhibitor herbicides. In Mexico, *P. minor* resistance to clodinafop, fenoxaprop, fluazifop-P-butyl, pinoxaden, sethoxydim and tralkoxydim has been reported *(http://www.weedresearch.com/Case/Case.asp?ResistID=5477).* Resistance in *P. minor* biotypes to clodinafop, diclofop, fenoxaprop, haloxyfop-P-methyl, iodosulfuron-methyl-sodium, mesosulfuron-methyl, propaquizafop, quizalofop-P-tefuryl and sulfosulfuron in S. Africa, USA and Israel has been documented earlier (Singh, 2006, 2007). The resistance pattern to different herbicides in *P. minor* biotypes may be due to their use under different cropping patterns. *P. minor* is major weed of wheat in India and quizalofop is not selective to wheat, but the resistant populations were effectively killed by quizalofop in pots (Fig. 2). Pinoxaden was found effective against isoproturon, clodinafop and fenoxaprop resistant biotypes (Figs. 2 and 5), but some variations have been observed in clodinafop resistant biotypes of *P. minor*. These variations to application rates have also been reported earlier (Chhokar and Sharma, 2008; Dhawan *et al*., 2010). Similarly, regrowth has been observed in *P. minor* biotypes treated with sulfosulfuron+metsulfuron and mesosulfuron+ iodosulfuron under both pots and field studies (Singh *et al*. 2009). For effective control of *P. minor* several factors need to be considered including proper spraying and rotation of herbicides.

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