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Studies on efficacy of pre-mix penoxsulam + pendimethalin on weed yield of direct seeded rice

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Abstract

The present investigation entitled "Studies on efficacy of pre- mix penoxsulam + pendimethalin on weed growth, yield and economics of direct seededrice" was carried out at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur during *kharif* season of 2015. The soil of experimental field was sandy loam in texture (*Inceptisols*), neutral in pH and has 0.44% organic carbon, low nitrogen, medium phosphorus and high potassium content. Experiment was laid out in Randomized Block Design (RBD) with three replications. The treatments consisted of fourteen different weed management treatments viz, T_1 Penoxsulam + Pendimethalin (10+240 g/l) SE @ 20 + 480 g a.i. ha^{-1}, T_2 Penoxsulam + Pendimethalin (10+240 g/l) SE @ 22.5 + 540 g a.i. ha^{-1}, T_3 Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1}, T_4 Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1}, T_5 Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1}, T_6 Penoxsulam 24% SC 20 g a.i. ha^{-1}, T_7 Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1}, T_8 Penoxsulam 24% SC @ 25 g a.i. ha^{-1}, T_9 Pendimethalin 30% EC @ 540 g a.i. ha^{-1}, T_{10} Pendimethalin 30% EC @ 600 g a.i. ha^{-1}, T_{11} Pendimethalin 30% EC @ 1000 g a.i. ha^{-1}, T_{12} Pendimethalin 30% EC @ 1500 g a.i. ha^{-1}, T_{13} hand weeding at 20 and 35 DAS and T_{14} untreated check. The result yield attributing characters like effective tillers m^{-2}, number of total and filled grains $panicle^{-1}$, panicle weight, panicle length, grain and straw yield. It was followed by treatments Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1} (T_4) and hand weeding at 20 and 35 DAS (T_{13}). Weed density, weed dry weight and weed control efficiency were significantly influenced by different weed control treatments. Treatment Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T_5) showed good performance with minimum weed dry weight, highest weed control efficiency and lowest weed index followed by Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1} (T_4) and hand weeding at 20 and 35 DAS (T_{13}). The number of spikelets $panicle^{-1}$, filled grains $panicle^{-1}$, panicle length and panicle weight were found to be reduced in untreated check (T_{14}) as a result of weed competition.

Keywords: Penoxsulam and pendimethalin

1. Introduction

Rice (*Oryza sativa* L.) is the most consumed cereal grain in the world, constituting the dietary staple food for more than half of the planet's human population. In world, rice is the second most widely consumed cereal next to wheat and it has occupied an area of 156.7 m ha, with a total production of 650.2 m t in 2014-15. According to the Food and Agriculture Organization (FAO) of the U.N. (2015), 80% of the world rice production mainly comes from Asian countries and Brazil. Among these countries, China is the largest producer of rice with a production of 197.26 m t and occupying an area of 30.30 m ha and with a productivity of 6.59 t ha^{-1}. In Asian countries, rice is major staple crop covering about ninety per cent of rice grown in the world. Hence, there is a need to increase the productivity of rice. (Anonymous, 2015a) [1]

Rice is the backbone of the Indian agriculture being the main source of livelihood for more than 150 million rural households. In India, total rice crop area is 41.85 m ha and production is 133.29 m t and average productivity is 3.12 t ha^{-1}. It occupies about 23.3 per cent of the food grain production and 55 per cent of cereal production. The rice plays a very vital role in the national food security. In India, rice is grown under three major ecosystems: rainfed uplands (16%), irrigated lands (45%) and rainfed low lands (39%), with a productivity of 0.87, 2.24 and 1.55 t ha^{-1}, respectively(Anonymous, 2015b) [2].

Rice production system is undergoing several changes and one of such change is shift from transplanted rice to direct seeding. The main driving forces of these changes are the rising wage rate, non availability of labour and scarcity of water. Direct seedling offers certain advantages i.e. saves labour, faster and easier planting helps in timely sowing, less drudgery, early crop maturity by 7-10 days, less water requirement, high tolerance to water deficit, often higher yield, low production cost and more profit, better soil physical condition for following crops and less methane emission (Balasubramanian and Hill, 2002) [4]

2. Material and Method

2.1 Number of effective tillers m^{-2}

The observations on number of panicle bearing tillers were made at harvest. Panicle bearing tillers were counted randomly from five plants and then average was worked out.

2.2 Panicle lengths (cm)

The length of panicle was taken from five panicles selected randomly from net plot area. It was measured from the neck-node to the tip of the apical grains.

After this, average length of panicle was determined.

2.3 Number of total, filled and unfilled grains panicle^{-1}

The panicles collected for measurement of length were used to count, Number of total, filled and unfilled grains and then average was calculated.

2.4 Sterility percentages

The number of filled and unfilled spikelets per panicle was counted from five panicles selected randomly for measurement of panicle length and sterility percentage was computed with the following formula:

$$\text{Sterility percent} = \frac{\text{Number of unfilled spikelets panicle}^{-1}}{\text{Total number of spikelets panicle}^{-1}} \times 100$$

2.5 Test weight (g)

A random grain samples were taken from the produce of each net plot. Out of the samples, 1000 grains were counted from each net plot and same were dried in oven at 60°C to constant weight, thereafter, weight so obtained was noted as 1000 grain weight (test weight).

2.6 Grain and straw yield (t ha^{-1})

After proper sun-drying, the production of the net plot was tied in bundles and weighed to determine the dry matter produce (grain + straw). The clean grain obtained after threshing and winnowing from each net plot was weighed. The straw yield was obtained by subtracting weight of the grain yield from the total weight of the bundle.

2.7 Harvest index (%)

Harvest index (HI) was calculated by the following formula:
Grain yield

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield (grain + straw)}} \times 100$$

3. Results and Discussion

3.1 Number of effective tillers (No. m^{-2})

Grain yield of cereals is highly dependent upon the number of effective tillers produced by each plant. The data given in Table 1 indicate that, almost all the treatments recorded significantly higher number of effective tillers m^{-2} over weedy check (T_{14}). However, treatment Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T_5) registered highest number of effective tillers which was significantly superior over others, but application of Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1} (T_3), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1} (T_4), Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1} (T_7), Penoxsulam 24% SC @ 25 g a.i. ha^{-1}(T_8) and hand weeding at 20 and 35 DAS (T_{13}), recorded at par effective tillers m^{-2}. The lowest number of effective tillers m^{-2} was noted under weedy check (T_{14}).

Higher number of effective tillers under Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T_5) and in above comparable treatments were due to the fact that there was more space to the crop to show their potential due to lower weed competition in terms of dry matter of weeds as well as good source sink relationship which allow crop to absorb required amount of nutrient, water and sunlight for its growth and tillering behavior. These results are in accordance with the findings of Mukherjee (2006), Singh and Singh (2006), Hasazzaman and Karim (2007) [11] and Yadav *et al*. (2009) [15].

3.2 Panicle length (cm)

The data on panicle length as affected by various treatments are presented in Table 1. A close observation of data reveals that it was significantly influenced by herbicides treatment. All the herbicides as well as hand weeding at 20 and 35 DAS (T_{13}) produced significantly longer panicle than weedy check (T_{14}).

The maximum length of panicle was recorded under Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T_5) which was significantly superior over others, however, it was at par with treatments Penoxsulam + Pendimethalin (10+240 g/l) SE @ 22.5 + 540 g a.i. ha^{-1} (T_2), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1} (T_3), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1} (T_4), Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1} (T_7), Penoxsulam 24% SC @ 25 g a.i. ha^{-1}(T_8) and hand weeding at 20 and 35 DAS (T_{13}). The shortest panicle was recorded under weedy check (T_{14}).

Longer panicle under these treatments might be due to minimum crop weed competition which allowed more growth of rice because of more availability of light, moisture, nutrients and space leads to production of longer size of panicle. Similar findings have been also reported by Narwal *et al*. (2002) [12] and Singh *et al*.

3.3 Panicle weight (g)

The data on panicle weight as affected by various treatments are presented in Table 1. All the herbicidal treatments showed significant impact on panicle weight as compared to untreated check (T_{14}). Maximum panicle weight was recorded under Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T_5). However, application of Penoxsulam + Pendimethalin (10+240 g/l) SE @ 22.5 + 540 g a.i. ha^{-1} (T_2), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1} (T_3), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1} (T_4), Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1} (T_7), Penoxsulam 24% SC @ 25 g a.i. ha^{-1}(T_8) and hand weeding at 20 and 35 DAS (T_{13}) were also found at par to Pendimethalin @ 100 + 2400 g a.i. ha^{-1} (T_5). Higher panicle length of the above treatment could be responsible for higher panicle weight; herbicides which facilitate the better transfer of photosynthates to the sink which contributes more to increase the weight of panicles. These findings are in accordance with those of Nerwal *et al*. (2002) [12], Singh *et al*.

(2006), Subramaniyam *et al*. (2007) [14] and Yadav *et al*. (2007).

3.4 Total number of grains panicle^{-1}

The data on total number of grains panicle^{-1} as affected by various treatments are presented in Table 2. Application of Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T_5) recorded maximum number of total grains panicle^{-1}. However, it was at par to Penoxsulam + Pendimethalin (10+240 g/l) SE @ 22.5 + 540 g a.i. ha^{-1} (T_2), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1} (T_3), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1} (T_4), Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1} (T_7), Penoxsulam 24% SC @ 25 g a.i. ha^{-1}(T_8) and hand weeding at 20 and 35 DAS (T_{13}). The lowest total number of grains panicle^{-1} was noted in weedy check (T_{14}). The higher number of grains panicle^{-1} recorded in these treatments might be due to the lower weed competition in terms of dry matter of weeds which create overall congenial environment for growth and development of rice resulted more availability of light, moisture, nutrients and space for rice plant leads to produce more number of sound grains panicle^{-1}. The result of present investigation is in agreement with the findings of Saini *et al*. (2001) and Narwal *et al*. (2002) [12]. They too reported that application of herbicides responded well with respect to production of number of grains panicle^{-1} as compared to other treatments. Another possible reason to obtain maximum number of grain panicle^{-1} might be due to effective weed control and weed control efficiency in herbicidal treated plot.

3.5. Filled and unfilled grains panicle^{-1}

The data on filled and unfilled grains panicle^{-1} as affected by various treatments are presented in Table 2. Treatment Penoxsulam + Pendimethalin @ 100 + 2400 g a.i. ha^{-1} (T_5) recorded maximum number of filled and minimum number of unfilled grains panicle^{-1}. As regards to filled and unfilled grains panicle^{-1}, the best performing treatment Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T_5) was at par to Penoxsulam + Pendimethalin (10+240 g/l) SE @ 22.5 + 540 g a.i. ha^{-1} (T_2), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1} (T_3), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1} (T_4), Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1} (T_7), Penoxsulam 24% SC @ 25 g a.i. ha^{-1}(T_8) and hand weeding at 20 and 35 DAS (T_{13}), The lowest number of filled grains panicle^{-1} was noted in untreated check (T_{14}), whereas this treatment also recorded the highest number of unfilled grains panicle^{-1}.

The lowest number of unfilled grains panicle^{-1} in treatments Penoxsulam + Pendimethalin (10+240 g/l) SE @ 22.5 + 540 g a.i. ha^{-1} (T_2), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1} (T_3), Penoxsulam + Pendimrthalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1} (T_4), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T_5), Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1} (T_7), Penoxsulam 24% SC @ 25 g a.i. ha^{-1}(T_8) and hand weeding at 20 and 35 DAS (T_{13}) might be due to the lower weed competition in terms of dry matter of weeds which create overall agreeable environment for growth and development of rice resulted more availability of light, moisture, nutrients and space for rice plant leads to produce more number of sound grains panicle^{-1}. Another possible reason to obtain maximum number of filled grains

Panicle^{-1} might be due to effective weed control and highest weed control efficiency in herbicidal treated plot. Other researchers found that application of herbicides responded well with respect to production of number of grains panicle^{-1} as compared to others treatments. Similar results were also reported by Narwal *et al*. (2002) [12], Singh *et al*. (2006) and Yadav *et al*. (2007).

3.6 Sterility percentage (%)

The mean value showing the influence of various treatments on the sterility percentage is presented in Table 2. Sterility percentage was lower under all the weed management practices than weedy check. The minimum (4.56%) sterility percentage was recorded under Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T_5) followed by Penoxsulam + Pendimethalin (10+240 g/l) SE @ 22.5 + 540 g a.i. ha^{-1} (T_2), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1} (T_3), Penoxsulam + Pendimrthalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1} (T_4), Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1} (T_7), Penoxsulam 24% SC @ 25 g a.i. ha^{-1}(T_8) and hand weeding at 20 and 35 DAS (T_{13}) which were statistically similar. It was established fact that there was severe crop-weed competition under the weedy check plot. The higher weed competition under weedy check arrested the nutrients and moisture available to rice crop. This, in turn, reduces the translocation of food material from source to sink resulted in higher sterility. As we know that weeds leads to imbalance uptake of nutrients, moisture, utilization of light and space, consequently affecting filling of grain adversely. Crop subject with higher competition for moisture, nutrients, light and space would definitely show high rate of sterility percentage owing to restricted transformation and translocation of food materials (Singh and Singh, 2006 and Yadav *et al*. 2007).

3.7 Test weight (g)

The weight of thousand grains is also an important attributes to yield and data are presented in Table 2. Among the treatments, 1,000 grain weights were not statistically different. The findings are supported by the observations of Matsushima (1980) who stated that the weight of 1,000 grains always shows the least variation under any cultural season and practices, compared to other components. Test weight is a varietal character because the grain size is rigidly controlled by the size of the hull (Yoshida, 1981). Rao and Moody (1992) mentioned that weed competition did not affect seed weight of the rice. This finding coincides with Razia (2000) who found the similar non-significant effects of weed competition on 1,000 grain weight. The present findings are in conformity with the results of Iqbal *et al*. (2008) who reported that 1,000 grain weight is a genetic character widely used in yield estimation and varietal selection in rice and environmental factors have minimum influence on it.

3.8 Grain yield (t ha^{-1})

The perusal of data given in Table 3 reveal that treatment Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T_5) registered significantly highest grain yield (4.74 t ha^{-1}), however, it was found at par with the application of Penoxsulam + Pendimethalin (10+240 g/l) SE @ 22.5 + 540 g a.i. ha^{-1} (T_2) (3.63 t ha^{-1}), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1} (T_3) (3.78 t ha^{-1}), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50+1200 g a.i. ha^{-1} (T_4) (4.64 t ha^{-1}), Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1} (T_7) (4.03 t ha^{-1}), Penoxsulam 24% SC @ 25 g a.i.

ha^{-1}(T$_8$) (4.28 t ha^{-1}) and hand weeding at 20 and 35 DAS (T$_{13}$) (4.45 t ha^{-1}). The minimum grain yield was observed under untreated check (T$_{14}$) (0.63 t ha^{-1}). Similar results were also reported by Gogoi *et al*. (1995), Nerwal *et al*. (2002) [12], Yadav *et al.* (2009) [15] and Halder and Patra (2010).

Grain production, which is the final product of growth and development, is controlled by dry matter accumulation during the ripening phase (De Datta, 1981). All the herbicidal treatments significantly influenced grain yields compared with unweeded check. Grain yield in weeding treatments were significantly higher than that of unweeded check. These results agreed on the findings of IRRI (1990) which reported that yields of weeded plots were consistently higher than those of unweeded.

Upadhyay and Gogoi (1993) concluded that the yield loss occurs 25-30% due to unchecked weed growth in direct seeded rice. The occurrence of weeds has become a serious problem and they limit the yield and quality of crops. It is often stated that some weeds cause total crop failure and that weeding practices are absolutely essential. Unchecked weed compete with rice plants for light, nutrients and moisture resulting reduction of grain yield up-to 80% (De Datta and Haque, 1982).

Contrarily, the poor growth of plants as well as development of yield attributing characters in control might be due to less moisture, nutrient, space and light available at the time of flowering and grain development adversely influenced the grain yield. The lower grain yield under control may be due to the high weed interference and less number of effective tillers (Behera and Jha, 1992) [5].

3.8 Straw yield (t ha^{-1})

The data on straw yield under different treatments have been presented in Table 3. The straw yield was significantly influenced by different treatments. Application of Penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. ha^{-1} (T$_5$) (5.19 t ha^{-1}) produced the highest straw yield and it was significantly superior to others but it was at par to application of Penoxsulam + Pendimethalin (10+240 g/l) SE @ 22.5 + 540 g a.i. ha^{-1} (T$_2$) (4.54 t ha^{-1}), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1} (T$_3$) (4.63 t ha^{-1}), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50+1200 g a.i. ha^{-1} (T$_4$) (5.16 t ha^{-1}), Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1} (T$_7$) (4.76 t ha^{-1}), Penoxsulam 24% SC @ 25 g a.i. ha^{-1}(T$_8$) (5.01 t ha^{-1}) and hand weeding at 20 and 35 DAS (T$_{13}$) (5.11 t ha^{-1}). The minimum straw yield was noted under untreated check (T$_{14}$) (1.55 t ha^{-1}). It can be inferred that treatments T$_4$, T$_5$ and T$_{13}$ checked the weeds in comparison to other treatments leading to higher grain and straw yield. While, in untreated check (T$_{14}$) reverse trends was observed and therefore, the lowest straw yield was noted under this treatment. Similar findings were also reported by Ashraf *et al.* (2006) [3].

3.9 Harvest index (%)

The data on harvest index for different treatments have been presented in Table 3. Application of penoxsulam + Pendimethalin (10+240 g/l) SE @ 100 + 2400 g a.i. (T$_5$) registred significantly higher harvest index than others, however, it was at par to treatments Penoxsulam + Pendimethalin (10+240 g/l) SE @ 22.5 + 540 g a.i. ha^{-1} (T$_2$), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 25 + 600 g a.i. ha^{-1} (T$_3$), Penoxsulam + Pendimethalin (10+240 g/l) SE @ 50 + 1200 g a.i. ha^{-1} (T$_4$), Penoxsulam 24% SC @ 22.5 g a.i. ha^{-1} (T$_7$), Penoxsulam 24% SC @ 25 g a.i. ha^{-1}(T$_8$) and hand weeding at 20 and 35 DAS (T$_{13}$). The lowest harvest index was observed under untreated check (T$_{14}$). The highest harvest index in above treatments (T$_2$, T$_3$, T$_4$, T$_5$, T$_7$, T$_8$ and T$_{13}$) was due to higher economic yield *i.e.* grain yield in proportion to straw yield because of low crop-weed competition. While, the lowest harvest index was observed in untreated check (T$_{14}$) due to more crop-weed competition.

The possible reason of lower harvest index may be due to the more competition during the critical periods which results in lower number of tillers, leaves, less number of grains and lower translocation of photosynthates towards the reproductive parts of the crop plant and act as a barrier for lower economic as well as biological yield. Deberman and Fairhurst (2000) reported that estimation of yield losses caused by competition from weeds ranges from 30-100%. This indicates that heavy weed infestation has caused a substantial reduction in the yield of rice. A yield loss from weeds in rice varies with the type of culture, method of planting, time of weed infestation, soil fertility and cultivar (De Datta *et al.*, 1969) [6].

Table 1: No. of effective tillers, panicle length, panicle weight and total number of grains as influenced by combination of herbicides

Treatment		Dosage		Time of application DAS	Effective tillers (No. m^{-2})	Panicle length (cm)	Panicle weight (g)	Total number of grains panicle^{-1}
		g a.i. ha^{-1}	Formulation ml ha^{-1}					
T$_1$	Penoxsulam + Pendimethalin (10+240 g/l) SE	20+480	2000	7	188.33	20.80	1.51	110.01
T$_2$	Penoxsulam + Pendimethalin (10+240 g/l) SE	22.5+540	2250	7	235.65	22.01	1.79	118.67
T$_3$	Penoxsulam + Pendimethalin (10+240 g/l) SE	25+600	2500	7	260.87	22.91	1.80	119.00
T$_4$	Penoxsulam + Pendimethalin (10+240 g/l) SE	50+1200	5000	7	286.65	23.36	2.23	129.74
T$_5$	Penoxsulam + Pendimethalin (10+240 g/l) SE	100+2400	10000	7	301.65	23.50	2.32	131.33
T$_6$	Penoxsulam 24% SC	20	83.33	7	170.80	13.59	1.42	106.67
T$_7$	Penoxsulam 24% SC	22.5	93.75	7	261.65	22.25	1.82	120.43
T$_8$	Penoxsulam 24% SC	25	104.17	7	274.98	22.32	2.03	123.33
T$_9$	Pendimethalin 30%EC	540	1800	7	106.65	18.16	1.30	98.36
T$_{10}$	Pendimethalin 30%EC	600	2000	7	125.83	19.03	1.36	103.42
T$_{11}$	Pendimethalin 30%EC	1000	3333.33	7	222.50	21.28	1.54	113.00
T$_{12}$	Pendimethalin 30%EC	1500	5000	7	207.50	21.27	1.53	111.73
T$_{13}$	Hand weeding	NA	NA	20 & 35	278.33	23.18	2.10	125.13
T$_{14}$	Untreated check	-	-	-	61.65	11.77	0.92	92.67
SEm±					14.03	0.76	0.26	4.74
CD (P=0.05)					40.81	2.22	0.77	13.78

Table 2: No. of filled grains, unfilled grains, sterility percentage and test weight as influenced by combination of herbicides

Treatment		Dosage g a.i. ha⁻¹	Dosage Formulation ml ha⁻¹	Time of application DAS	Filled grain panicle⁻¹	Unfilled grain panicle⁻¹	Sterility percentage	Test weight (g)
T_1	Penoxsulam + Pendimethalin (10+240 g/l) SE	20+480	2000	7	91.77	14.33	12.87	23.91
T_2	Penoxsulam + Pendimethalin (10+240 g/l) SE	22.5+540	2250	7	106.67	10.67	9.58	23.88
T_3	Penoxsulam + Pendimethalin (10+240 g/l) SE	25+600	2500	7	109.33	10.66	9.40	23.86
T_4	Penoxsulam + Pendimethalin (10+240 g/l) SE	50+1200	5000	7	119.40	6.32	4.91	24.27
T_5	Penoxsulam + Pendimethalin (10+240 g/l) SE	100+2400	10000	7	123.21	5.98	4.56	24.32
T_6	Penoxsulam 24% SC	20	83.33	7	87.70	14.33	13.53	23.84
T_7	Penoxsulam 24% SC	22.5	93.75	7	111.00	8.67	7.18	23.70
T_8	Penoxsulam 24% SC	25	104.17	7	112.33	8.33	6.77	23.98
T_9	Pendimethalin 30%EC	540	1800	7	76.07	20.33	20.72	22.99
T_{10}	Pendimethalin 30%EC	600	2000	7	83.11	18.00	18.09	23.89
T_{11}	Pendimethalin 30%EC	1000	3333.33	7	96.33	12.67	11.28	23.75
T_{12}	Pendimethalin 30%EC	1500	5000	7	92.08	13.97	12.90	23.98
T_{13}	Hand weeding	NA	NA	20 & 35	115.67	8.00	6.41	24.02
T_{14}	Untreated check	-	-	-	71.14	22.33	24.18	22.85
SEm±					5.73	1.72	1.76	0.38
CD (P=0.05)					16.65	5.01	5.13	NS

Table 3: No. of filled grains, unfilled grains, sterility percentage and test weight as influenced by combination of herbicides

Treatment		Dosage g a.i. ha⁻¹	Dosage Formulation ml ha⁻¹	Time of application DAS	Grain yield (t ha⁻¹)	Straw yield (t ha⁻¹)	HI (%)
T_1	Penoxsulam + Pendimethalin (10+240 g/l) SE	20+480	2000	7	3.34	4.32	43.04
T_2	Penoxsulam + Pendimethalin (10+240 g/l) SE	22.5+540	2250	7	3.63	4.54	44.41
T_3	Penoxsulam + Pendimethalin (10+240 g/l) SE	25+600	2500	7	3.78	4.63	45.04
T_4	Penoxsulam + Pendimethalin (10+240 g/l) SE	50+1200	5000	7	4.64	5.16	47.31
T_5	Penoxsulam + Pendimethalin (10+240 g/l) SE	100+2400	10000	7	4.74	5.19	47.87
T_6	Penoxsulam 24% SC	20	83.33	7	3.13	4.21	42.70
T_7	Penoxsulam 24% SC	22.5	93.75	7	4.03	4.76	45.86
T_8	Penoxsulam 24% SC	25	104.17	7	4.28	5.01	45.91
T_9	Pendimethalin 30%EC	540	1800	7	1.81	3.71	32.23
T_{10}	Pendimethalin 30%EC	600	2000	7	2.13	3.84	34.88
T_{11}	Pendimethalin 30%EC	1000	3333.33	7	3.50	4.53	43.95
T_{12}	Pendimethalin 30%EC	1500	5000	7	3.38	4.32	43.89
T_{13}	Hand weeding	NA	NA	20 & 35	4.45	5.11	46.58
T_{14}	Untreated check	-	-	-	0.63	1.55	29.65
SEm±					0.42	0.22	1.30
CD (P=0.05)					1.24	0.66	3.77

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