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Effect of overall and row application of herbicides on growth, yield and economics of potato (*Solanum tuberosum*)

Santanu Das, B Duary and Jagadish Jena

Abstract
A field experiment was conducted during the *rabi* season of 2014-15 at farmer's field of village Ballavpur, Birbhum, West Bengal with potato variety 'Kufri jyoti' to study the effect of overall and row application of different herbicides on growth, yield and economics of potato. The experiment was comprised of ten treatments and was laid out in a randomized block design with three replications. Higher values of growth and yield attributes and yield of potato, net return as well as return per rupee invested were registered with application of metribuzin at 200 g ha^{-1} as pre-emergence in row only. However, it was at par with metribuzin at 400 g ha^{-1} as pre-emergence with overall application as well as two earthing up at 25 and 50 DAP. Weed infestation caused about 41.2% tuber yield reduction in potato. Thus it appeared that pre-emergence application of metribuzin at 200 g ha^{-1} in rows only showed promising results in managing complex weed flora registering the highest gross return, net return and return per rupee invested in potato cultivation.

Keywords: Potato, earthing up, herbicide, metribuzin

Introduction
Potato (*Solanum tuberosum* L.) is a wholesome food crop and is used as a staple food in several developed countries. Potato is used as vegetable, stock feed and in industries for manufacturing starch, alcoholic beverages and other processed products. It is a highly nutritious food. It contains 20.6% carbohydrates, 2.1% protein, 0.3% fat, 1.1% crude fiber and 0.9% ash (Yadav and Srivastava, 2015) [11]. It also contains good amounts of essential amino acids like leucine, tryptophan and isolucine (Paul, 2003) [7]. Potatoes yield about 97 Kilo calories per 100 g fresh weight, which is much higher than cereals. Potato also contains considerable quantities of niacin, thiamine, pyridoxine and its derivatives (Yadav and Srivastava, 2015) [11]. The flexibility in growing period makes it highly amenable to adjustment in cropping systems without sacrificing acreage and minimal or no loss in yield of crops (Singh *et al.,* 2008) [9]. Potato being a short duration crop gave ample and economical tuber yield in 75 -80 days.

Information on weed control is limited as regard to the major potato growing areas of West Bengal. Weeds grow luxuriantly and pose a serious problem in potato cultivation competing for nutrients, moisture, space and light and often serve as alternate hosts for several insect and diseases which causes 15-65% yield losses (Tomar *et al.,* 2008, Chandrakar *et al.,* 2014 and Yadav *et al*., 2014) [10, 1, 12]. In addition shortage of labour supply during the peak period and high wages force the farmers to neglect weed management practices. In order to have maximum benefit of supplied monetary inputs, weed management at critical stages of crop weed competition is inevitable. The conventional system of weed control supposes the applying of one or more herbicides evenly on the entire cultivated area, but the weed spectrum and the distribution of weed population is not even, leading to a needless pollution of the soil (Loken *et al.,* 2006; Lassiter *et al.,* 2008) [4, 3]. The agricultural precision system, the most efficient sustainable agricultural system supposes applying technological measures precisely as and when needed depending on the particularities of each soil type (Lopezgranados, 2011) [5].

In potato earthing up is an essential practice which also facilitates weeding in between rows of the crop. But many weeds which appear within rows cause considerable damage in potato. Herbicides are recommended for managing the weeds both within and in between rows of potato.

However, it is hardly required to apply herbicides blanketly over the whole area as earthing up is practiced in between rows. Furthermore this unnecessary application of herbicides may lead to negative impact and increase herbicide load in the environment. The quantity of herbicides applied may be reduced with precision application only within the rows of potato with the aim of reducing herbicide load in the environment. Thus it is imperative to compare the efficacy of blanket application of herbicides in recommended dose and with half of the recommended dose precisely applied only in the rows of the crop. Keeping these in mind, the present experiment entitled "Comparative studies between overall and row application of herbicides in potato (*Solanum tuberosum* L.)" was conducted with the objective to study the effect of overall and row application of different herbicides on growth, yield and economics of potato.

Materials and methods

The experiment was conducted during *Rabi* season of 2014-2015 at the farmer's field of Ballavpur, Birbhum, West Bengal. The field is situated at about 23.6831′N latitude and 87.6556′E longitude with an average altitude of 81.5 m above the mean sea level. The experimental plot was having sandy loam soil with medium to low fertility status and acidic pH. The texture and chemical properties of the experimental soil are as follows.

Table 1: The physic-chemical properties of the Experimental soil

Mechanical analysis				Chemical analysis			
Sand %	**Silt %**	**Clay %**	**pH**	**Organic Carbon %**	**Available N (Kg ha^{-1})**	**Available P (Kg ha^{-1})**	**Available K (Kg ha^{-1})**
66.60	16.70	16.70	5.24	0.42	119.36	14.90	124.26

Mechanical analysis: International Pipette method as described by Piper (1942), Soil pH: Determined with pH meter in 1: 2.5 ratio of soil: water suspension as recommended by soil reaction committee (1930) and described by Jackson (1973), Organic Carbon: Volumetric wet combustion method described by Muhr *et al.* (1965)., Total nitrogen: Modified micro Kjeldahl method as described by Jackson (1973).

The field experiment was carried out in randomized block design (RBD) with ten treatments each replicated thrice. The treatments were as follows: T_1: Metribuzin at 400 g ha^{-1} as pre emergence (Over all application), T_2: Metribuzin at 200 g ha^{-1} as pre emergence (Row application), T_3: Metribuzin at 400 g ha^{-1} as post emergence (Over all application), T_4: Metribuzin at 200 g ha^{-1} as post emergence (Row application), T_5: Oxyfluorfen at 0.2 kg ha^{-1} as pre emergence (Over all application), T_6: Oxyfluorfen at 0.1 kg ha^{-1} as pre emergence (Row application), T_7: Pendimethalin at 1.0 kg ha^{-1} as pre emergence (Over all application), T_8: Pendimethalin at 0.5 kg ha^{-1} as pre emergence (Row application), T_9: Only 2 earthing up at 25 and 50 DAP, T_{10}: Unweeded control. One earthing up was common for all the treatments except T_9.

The potato variety *'Kufri Jyoti'* was used in the experiment. It is a high yielding variety with medium duration. It takes 90 days to mature. The production potential of the variety is about 20-25 t ha^{-1}. The herbicide pendimethalin (Stomp 30EC) and oxyfluorfen (Oxygold 23.5 EC) were applied as pre emergence. Metribuzin (Sencor 70WP) was applied both as pre and post emergence as per treatment. All the herbicides were sprayed with manually operated knap-sac sprayer fitted with flat fan nozzle using 500 litres of water per hectare. Weeding followed by earthing up were done at 25 days after planting (DAP), after the application of the remaining part of nitrogen fertilizers in the form of urea as per treatments. Another earthing up was given at 50 days after planting only for T_9 treatment.

The height of the plant was taken at 30, 45, 60 and 75 DAP. Five plants from each plot were uprooted from a row at 45, 60 and 75 DAP. The leaves stem and tubers were separated from the plants and the leaf areas of the green leaves were determined by leaf area meter for Leaf area index (LAI). Tubers were weighted for tuber bulking rate (TBR). The leaves, twigs and tubers were put in separate envelopes, for each plot and dried in a hot air oven at 65^{0}c for 72 hours till constant weights were obtained. Before drying, the tubers were chopped into small pieces. The dry weights recorded were used to determine leaf area index (LAI), Dry matter accumulation, crop growth rate (CGR), and tuber growth rate (TGR) at different growth periods.

The experimental data related to each character of crop and weed were analysed statistically by the technique of "Analysis of variance" and significance was tested by variance ratio i.e. *v*alue at 5% level of significance as described by Gomez and Gomez (2010). The standard error of means (S.Em.±), the value of critical differences (C. D.) to compare the differences between means, and co-efficient of variability (C.V.) have been provided in the tables of the chapter results and discussion. Weed data (e.g. population, dry weight) was usually square root transformed [$\sqrt{(X + 0.5)}$]. The original data has been given in parentheses in each table along with the transformed value. Non-significant difference was indicated as NS.

Results and discussions

Potato plant growth

Plant height

The plant height of potato at different stages increased as the crop progressed towards its maturity. The height varied significantly at 45, 60, 75 and 90 DAP. At these stages two earthing up at 25 and 50 DAP (T_9) registered the highest plant height and was at par with metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1) and metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2). This might be probably due to higher nutrient uptake and greater light interception by potato in these treatments resulting in vigorous growth including elongation of shoots as compared to that of other plots where weeds were not controlled effectively. The unweeded control plot (T_{10}) recorded the lowest plant height, which might be due to competition exerted by grassy and other weeds throughout the growth period of potato by overcrowding in crop-weed ecosystem. This corroborates the results of Tomar *et al.* (2008) [10], Denesh *et al*. (2011) [2], Mukherjee *et al.* (2012) [6], Pramanick *et al.* (2012) [8] and Yadav *et al.* (2014) [12].

Table 2: Effect of treatments on plant height and number of branches per plant of potato at different growth stages

Treatments	Plant height (cm)					Number of branches per plant		
	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	30 DAP	45 DAP	60 DAP
T_1	12.72	26.24	36.35	42.24	44.61	4.18	5.95	6.57
T_2	12.54	26.09	37.40	41.62	43.99	3.93	6.14	6.70
T_3	12.57	24.68	34.10	39.65	42.02	3.02	4.95	5.22
T_4	11.36	21.91	31.22	35.44	39.42	2.89	4.63	4.87
T_5	12.17	24.39	33.70	39.27	41.64	3.27	5.24	5.75
T_6	11.96	21.78	30.76	34.98	38.01	3.43	5.17	5.43
T_7	12.53	21.87	30.54	34.76	37.80	3.04	4.74	5.01
T_8	11.02	23.84	32.55	39.10	41.47	3.29	4.97	5.25
T_9	13.21	27.06	38.03	42.92	45.12	4.37	6.22	6.81
T_{10}	10.71	17.51	25.85	30.40	33.11	2.33	3.20	3.82
S. Em (±)	-	1.32	1.18	1.17	1.38	0.19	0.20	0.17
LSD (P=0.05)	NS	3.92	3.51	3.50	4.12	0.58	0.62	0.51
CV (%)	-	9.72	6.19	5.37	5.89	10.09	7.09	5.46

Number of branches per plant

The highest number of branches per plant was observed in two earthing up at 25 and 50 DAP (T_9) which was statistically at par with metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1) and metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2). The lowest number of branches was recorded in unweeded control plot (T_{10}) which was statistically at par with metribuzin at 200 g ha^{-1} as post emergence with row application only (T_4). Numbers of branches varied significantly when observation was recorded at 45 DAP. The highest number of branches was registered in two earthing up at 25 and 50 DAP (T_9) which was statistically at par with metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). The unweeded control plot recorded the lowest number of branches $plant^{-1}$ at 45 DAP.

The numbers of branches also varied significantly among the treatments when observation was recorded at 60 DAP. The highest number of branches was registered in two earthing up at 25 and 50 DAP (T_9) which was statistically at par with metribuzin at 200 gha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). The unweeded control plot (T_{10}) recorded the lowest number of branches $plant^{-1}$ followed bymetribuzin at 200 g ha^{-1} as post emergence with row application only (T_4).

Dry matter accumulation (g m^{-2})

The highest dry matter accumulation of potato at different growth periods was recorded under two earthing up at 25 and 50 DAP (T_9) which was statistically at par with metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). This was mainly due to higher weed control efficiency of these treatments which maintained lower weed density as well as dry weight thus least crop weed competition from the very early stage of the crop till maturity facilitating higher nutrient and water uptake, accelerated photosynthetic activity, availability of optimum space for better crop growth resulting into higher dry matter accumulation.

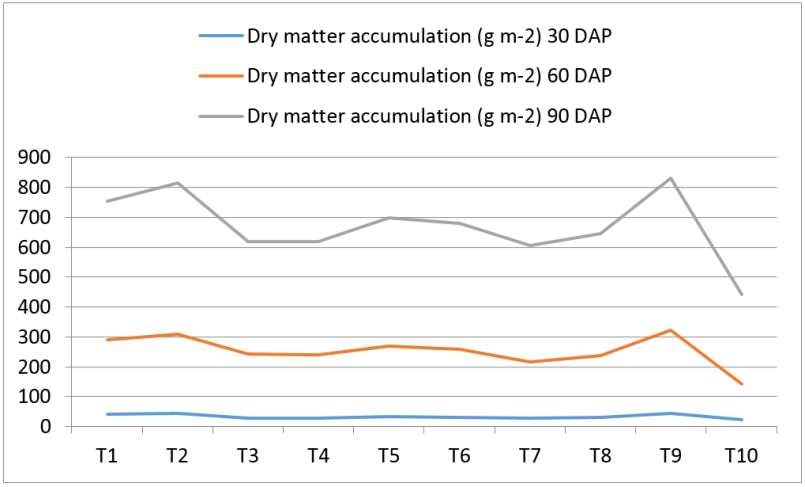

Fig 1: Effect of treatments on dry matter accumulation of potato at different growth stages

Leaf area index

The data on leaf area index (LAI) of potato at different growth stages were statistically analysed and presented in Fig. 2. It revealed that the LAI of potato at 45, 60 and 75 DAP varied significantly with different treatments.

In all the observations the highest LAI was observed in the plot treated with two earthing up at 25 and 50 DAP (T_9) which was at statistically at par with metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). This might be due to effective control of weeds by these treatments providing minimum weed competition in critical periods that accelerated photosynthetic activity ultimately leading to higher LAI. Among all the treatments the lowest LAI was observed in unweeded control.

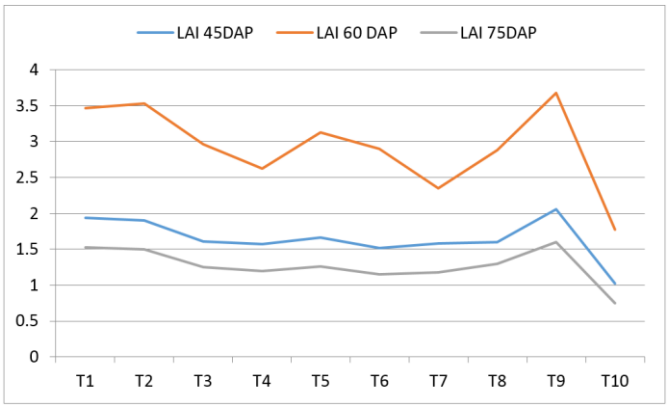

Fig 2: Effect of treatments on Leaf Area Index (LAI) of Potato

Crop growth rate (CGR)

The data on crop growth rate (CGR) during the period from 45-60 DAP, 60-75 DAP and 75-90 DAP of potato presented in Fig. 3 revealed that the CGR of potato varied significantly among the different treatments. During the period 45-60 DAP the highest crop growth rate was recorded with two earthing up at 25 and 50 DAP (T_9) which was statistically at par with metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application(T_1). The lowest CGR was observed in unweeded control (T_{10}) at 45 -60 DAP.

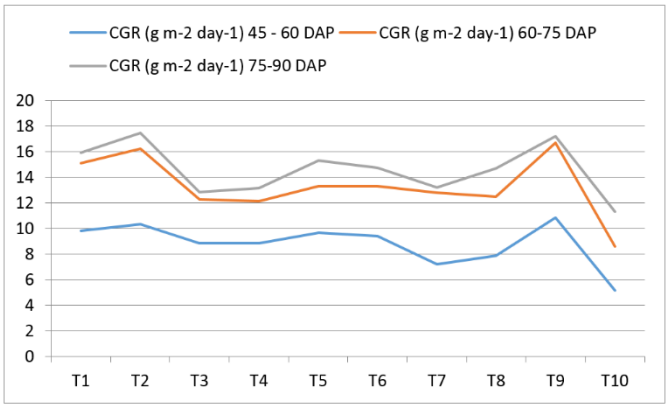

Fig 3: Effect of treatments on crop growth rate (CGR) of potato

During the period 60- 75 DAP the highest crop growth rate was recorded with two earthing up at 25 and 50 DAP (T_9) which was statistically at par with metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). However, all the herbicides as row application was statistically at par with overall application in double dose with respect to CGR at 60-75 DAP. The lowest crop growth rate was observed in unweeded control (T_{10}). Pre emergence application of metribuzin at 200 g ha^{-1} on row only (T_2) registered the highest CGR at 75-90 DAP which was statistically at par with two earthing up at 25 and 50 DAP (T_9) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). The lowest crop growth rate was observed in unweeded control (T_{10}) but it was at par withmetribuzin at 200 g ha^{-1} as post emergence with row application only (T_4) metribuzin at 400 g ha^{-1} as post emergence with overall application (T_3) and pendimethalin at 1 lit.ha^{-1} as pre emergence overall application (T_7). The plots treated with metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1) registered the highest CGR during the periods for which it was estimated under the study. It might be due to lower competition between potato and weeds resulting in higher dry matter accumulation and crop growth rate. On the other hand the lowest crop growth rate was registered with unweeded control (T_{10}) because of higher crop weed competition for these growing periods.

Tuber growth rate (TGR)

The data on tuber growth rate (TGR) during the period from 45-60 DAP, 60-75 DAP and 75-90 DAP of potato presented in Fig. 4 revealed that the TGR of potato varied significantly among the different treatments.

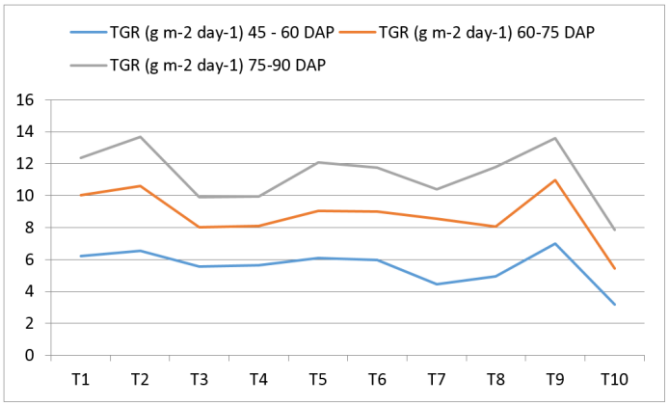

Fig 4: Effect of treatments on tuber growth rate (TGR) of potato

In all the observations the highest TGR was observed in the plots with two earthing up at 25 and 50 DAP (T_9) which was statistically at par with metribuzin at 200 gha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). It might be due to lower competition between potato and weeds resulting in higher dry matter accumulation and tuber growth rate. On the other hand the lowest tuber growth rate was registered with unweeded control (T_{10}) because of higher crop weed competition for these growing periods.

Tuber Bulking Rate (TBR)

The data on tuber bulking rate (TBR) during the period from 45-60 DAP, 60-75 DAP and 75-90 DAP of potato presented in Fig. 5 expressed that the TBR of potato varied significantly among the different treatments.

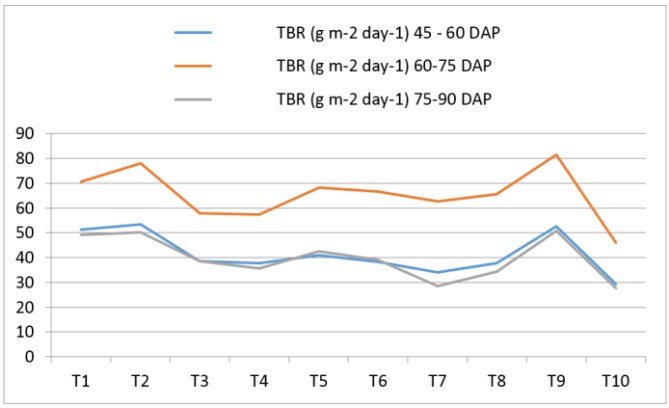

Fig 5: Effect of treatments on tuber bulking rate (TBR) of potato

The highest tuber bulking rate of potato at different growth periods was recorded under two earthing up at 25 and 50 DAP (T_9) which was statistically at par with metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and

metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). This was mainly due to higher weed control efficiency of these treatments which maintained lower weed density as well as dry weight thus least crop weed competition from the very early stage of the crop till maturity facilitating higher nutrient and water uptake, accelerated photosynthetic activity, availability of optimum space for better crop growth resulting into higher tuber bulking rate.

Yield components and yield

Number of tubers plant^{-1}

The data on number of tubers plant^{-1} of potato were statistically analysed and presented in fig. 6. The highest number of tubers plant^{-1} was recorded with two earthing up at 25 and 50 DAP (T_9) which was statistically at par with application of metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1) and metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2). This indicates that efficient and timely weed management practices by application of herbicide effectively controlled different spectrum of weeds appearing in differing flushes during the crop growing period and thereby promoted tuber formation of potato. Thus the potato faced less or no weed competition during its critical period that facilitated better growth and higher leaf area and dry matter accumulation for tuber formation. Similar findings were also reported earlier by Denesh *et al.* (2011) [2], Mukherjee *et al.* (2012) [6], Pramanick *et al.* (2012) [8] and Yadav *et al.* (2014) [12].

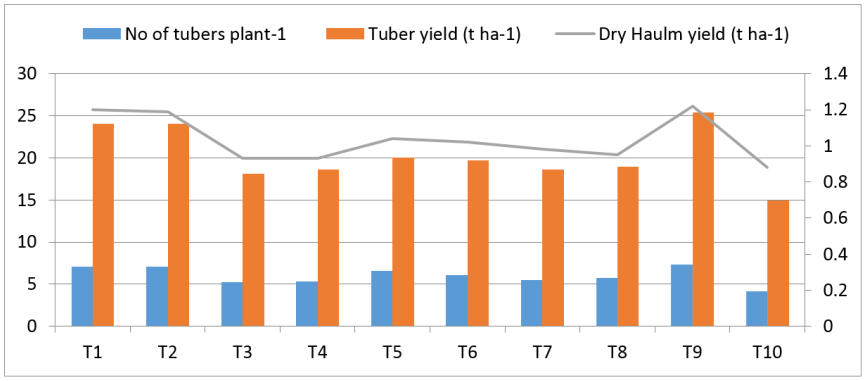

Fig 6: Effect of treatments on yield components and yield of potato

Tuber weight plant^{-1}

Tuber weight plant^{-1} of potato varied significantly among the treatments as evident from the Fig. 7. The highest tuber weight plant^{-1} was recorded with two earthing up at 25 and 50 DAP (T_9) which was statistically at par with metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). These treatments controlled all spectrum of weed effectively as evident from the data on weed population, weed dry weight and weed control efficiency. The competition between potato and weeds was minimum, which helped promoting growth attributes and partitioning dry matter towards tuber formation. The results corroborate the findings of Denesh *et al.* (2011) [2], Pramanick *et al.* (2012) [8] and Yadav *et al.* (2014) [12]. The lowest tuber weight plant^{-1} was observed under unweeded control (T_{10}) followed by metribuzin at 400 g ha^{-1} as post emergence with overall application (T_3) and pendimethalin at 1.0 kg ha^{-1} as pre emergence with overall application (T_7). The crop under these treatments faced severe weed competition for nutrient, light, water and space throughout the crop growth resulting in the lowest value of plant height, leaf area index and dry matter accumulation and ultimately recorded the lowest tuber weight plant^{-1}. The results are in agreements with the findings of Denesh *et al.* (2011) [2] and Yadav *et al.* (2014) [12].

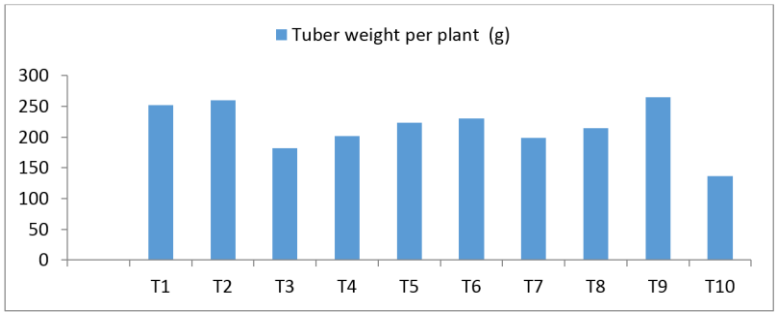

Fig 7: Effect of treatments on tuber yield per plant

Tuber yield (t ha^{-1})

The data on tuber yield of potato was statistically analyzed and presented in Fig. 6. It varied significantly among the treatments. There was about 41.2% tuber yield reduction due to weed competition in potato. Similar yield reduction in potato due to weed competition in West Bengal was also reported by with Mukherjee *et al.* (2012) [6] and Pramanick *et al.* (2012) [8]. The highest tuber yield was recorded under the treatment two earthing up at 25 and 50 DAP (T_9) which was statistically at par with metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). These treatments controlled whole spectrum of weeds effectively as evident from the data on weed density, dry weight and weed controlled efficiency. The competition between potato and weed for nutrient, water, light and space was less under the above nutrients, which facilitated greater utilization of sun light, higher synthesis of carbohydrate and

better partitioning of photosynthates towards tuber formation and ultimately leading to higher tuber yield of potato. Similar beneficial effect of weed management practices on potato tuber yield was reported by Tomar *et al.* (2008) [10], Denesh *et al.* (2011) [2], Mukherjee *et al.* (2012) [6], Pramanick *et al.* (2012) [8] and Yadav *et al.* (2014) [12].

The lowest tuber yield was observed under unweeded control (T_{10}). Yield could be limited either by supply of assimilates (source) or by the number and weight of tuber to be filled (sink) or by source and sink simultaneously (Fisher, 1983 and Evens, 1993). In the present study both source and sinks were limited because of weed competition as evident from the result of leaf area (source) and dry matter production and various yield component (sinks) in potato. These treatments could not suppress the weeds effectively during the crop growing period. Hence, potato faced severe competition for nutrients water, light and space throughout or part of the crop growing period as in case of unweeded control and registered low values leaf area index, dry matter accumulation, number of tubers plant^{-1}, tuber weight plant^{-1} and ultimately tuber yield of potato. The results corroborate the findings of Denesh *et al.* (2011) [2], Pramanick *et al.* (2012) [8] and Yadav *et al.* (2014) [12].

Dry haulm yield (t ha^{-1})

The data presented in Fig. 6 expressed that the haulm yield of potato varied significantly among the treatments. The highest haulm yield was recorded under the treatment two earthing up at 25 and 50 DAP (T_9) which was statistically at par with application of metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1) and metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2). Use of herbicide resulted in higher haulm yield of potato due to better control of weeds, lower competition between potato and weed and higher dry matter accumulation in vegetative organs that increased haulm yield. The results corroborate the findings of with Denesh *et al.* (2011) [2] and Pramanick *et al.* (2012) [8].

Grade wise tuber yield

The data on grade wise tuber yield of potato was statistically analyzed and presented in Fig. 8. It varied significantly among the treatments.

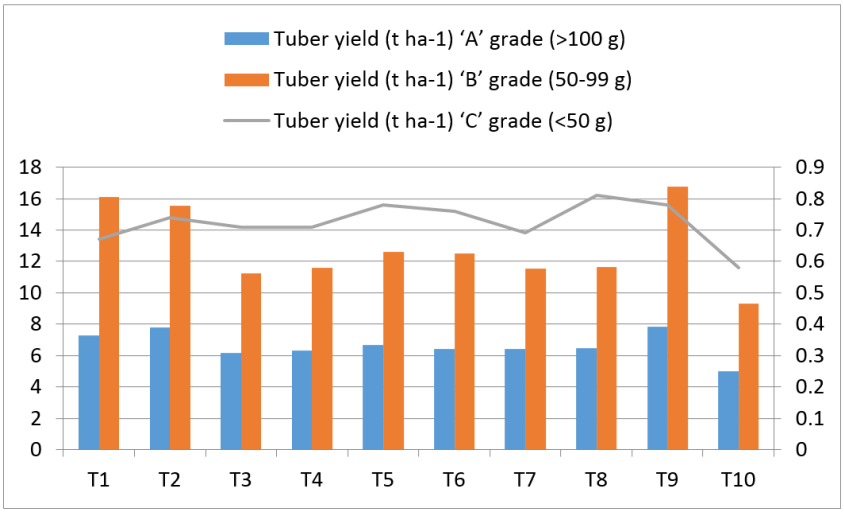

Fig 8: Effect of treatments on grade wise tuber yield of potato

Two earthing up at 25 and 50 DAP (T_9) registered the highest grade A tuber yield (>100 g) and grade "B" tuber yield (50-99 g) which was statistically at par with metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). The competition between potato and weed for nutrient, water, light and space was less under the above treatments which facilitated greater utilization of sun light, higher synthesis of carbohydrate and better partitioning of photosynthates towards tuber formation and ultimately leading to higher grade wise tuber yield of potato. Similar beneficial effect of weed management practices on potato tuber yield was reported by with Tomar *et al.* (2008) [10], Denesh *et al.* (2011) [2], Mukherjee *et al.* (2012) [6], Pramanick *et al.* (2012) [8] and Yadav *et al.* (2014) [12].

Economics of potato cultivation under different treatments

The economics of potato cultivation under different weed management practices were worked out in this experiment and presented in the Fig. 9.

Cost of cultivation (₹ ha^{-1})

The highest cost of cultivation was incurred towards with two earthing up at 25 and 50 DAP (T_9) followed by oxyfluorfen at 0.2 kg ha^{-1}as pre emergence with over all application (T_4). Among the herbicidal treatments metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) registered the lowest cost of cultivation over that of other treatments followed by metribuzin at 200 g ha^{-1}as post emergence with row application only (T_4). The results revealed that the cost of cultivation of potato with any type of herbicide application was higher than that of weedy check. This increased cost was due to herbicides and its application cost as compared to that of no weed management practices.

Gross return (₹ ha^{-1})

From the Fig. 9, it was found that the highest gross return (₹ ha^{-1}) was recorded in two earthing up at 25 and 50 DAP (T_9) followed by metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). The lowest gross return was obtained from unweeded control followed by pendimethalin at 1.0 kg ha^{-1} as pre-emergence with overall application (T_1).

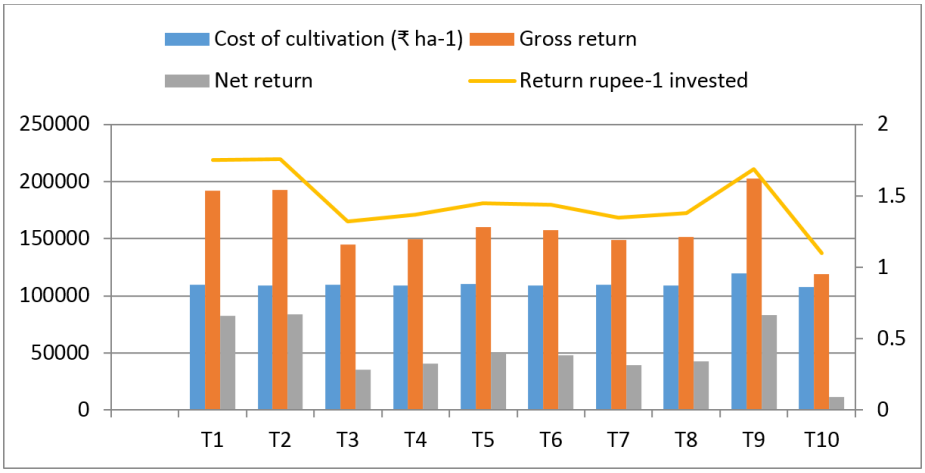

Fig 9: Economics of potato cultivation under different treatments

Labour cost @ ₹ 170/-, seed tuber @ ₹ 40/- kg^{-1}, Fertilizer: urea @ ₹ 7.5 kg^{-1}, 10:26:26 @ ₹ 24 kg^{-1}. Selling potato tuber @ ₹ 8/- kg^{-1}, Land preparation including tractor and labour @ ₹ 7500/- ha^{-1}, Potato seed tuber cutting and sowing (50 labours) ₹ 8500/- ha^{-1}, Ferlitilzer including application cost ₹ 18290 ha^{-1}, One earthing up (70 labours) ₹ 11900/- ha^{-1}, Seed treatment and plant protection ₹ 2625/- ha^{-1}, Irrigation ₹ 4000/- ha^{-1}, Harvesting and packaging (60 labours) ₹ 10200/- ha^{-1}, Herbicides: Metribuzin @ ₹ 200/- per 100 g, Oxyflorfen@ ₹ 240/- per 100 g, Pendimethalin@ ₹ 400/- 1 lit. Application cost of herbicides (2 labours) @ ₹ 340/- per ha.

Net return (₹ ha^{-1})

The data on net return presented in the Fig. 9, expressed that pre-emergence application of metribuzin at 200 g ha^{-1} on row only (T_2) recorded the highest net return followed by two earthing up at 25 and 50 DAP (T_9) and metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). This was due to higher tuber and haulm yield of the crop obtained from the above treatments and lower cost of cultivation. Unweeded control (T_{12}) fetched the lowest net return among all the treatments.

Return rupee^{-1} invested

The perusal of the data in the Fig. 9, expressed that the treatment metribuzin at 200 g ha^{-1} as pre emergence with row application only (T_2) gave the highest value of return per rupee invested followed by that of metribuzin at 400 g ha^{-1} as pre-emergence with overall application (T_1). The lowest value of return per rupee invested was recorded in unweeded control (T_{10}). The lowest gross return, net return and return rupee^{-1} invested were received from unweeded control (T_{10}) due to poor growth of the crop, greater competition between potato and weeds which led to produce the lower tuber and haulm yield. Similar results of higher net return due to weed management of herbicides over unweeded control were also reported earlier by Tomar *et al.* (2008) [10], Denesh *et al.* (2011) [2], Pramanick *et al.* (2012) [8] and Yadav *et al.* (2014) [12].

Conclusion

Metribuzin at 200 g ha^{-1} as pre-emergence in row only increased the values of growth attributes and yield of potato which were comparable with overall application of metribuzin at 400 g ha^{-1} as pre emergence and two earthing up at 25 and 50 DAP. Application of metribuzin at 200 g ha^{-1} as pre-emergence in row only also registered the highest gross return, net return and return per rupee invested. Thus it appeared that pre-emergence application of metribuzin at 200 g ha^{-1} in rows only with half of the recommended dose showed promising results in managing complex weed flora registering the highest gross return, net return and return per rupee invested in potato cultivation.

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