EFFECT OF CROP ESTABLISHMENT METHODS AND WEED MANAGEMENT OPTIONS ON WEED DYNAMICS AND PERFORMANCE OF BASMATI RICE (*Oryza sativa* L.)

THESIS

Submitted to

SARDAR VALLABHBHAI PATEL UNIVERSITY OF AGRICULTURE & TECHNOLOGY, MEERUT- 250110 (U.P.), INDIA

By

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Dedicated

to

My Beloved Parents

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CERTIFICATE

This is to certify that the thesis entitled "**Effect of crop establishment methods and weed management options on weed dynamics and performance of Basmati rice (*Oryza sativa* L.).**"submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** with major in **Agronomy** and minor in **Soil Science & Agricultural Chemistry** of the College of Post-Graduate Studies, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, is a record of bonafide research carried out by **Ms. Shipra Yadav, Id. No. 4253**, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

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We, the undersigned, members of the advisory Committee of **Ms. Shipra Yadav, Id. No. 4253**, a candidate for the degree of **Doctor of Philosophy** with major in **Agronomy** and minor in **Soil Science & Agricultural Chemistry** agree that the thesis entitled "**Effect of crop establishment methods and weed management options on weed dynamics and performance of Basmati rice (*Oryza sativa* L.).**"may be submitted by **Ms. Shipra Yadav,** in partial fulfillment of the requirements for the degree.

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CHAPTER-1 INTRODUCTION

Rice is major staple food crop of more than 3 billion people in the world and it contains 7-8% protein, 3% fat and 3% fiber. 100 gms of uncooked rice contains 80.40 gms of carbohydrates, of which 63.6% is starch, however, when rice is cooked, the starch content drops dramatically. It occupies 162.97 mha of area, producing 495.03 million tonnes of rice with an average productivity of 3.04 t/hain the world. In India, rice occupies an area of 43.79 mha with production and productivity of 116.42 mt and 2.65 t/ha,respectively (Anonymous, 2019). The major rice growing states in India are West Bengal, Uttar Pradesh, Assam, Bihar, Orissa and Madhya Pradesh. Uttar Pradesh is the 2nd largest rice growing state only after West Bengal in the country, in which rice is grown over an area of 5.75 mha with a production of 15.54 mt and the productivity of 2.70 t/ha (Anonymous, 2019). About 63 per cent of total rice area is situated in Uttar Pradesh, Bihar, West Bengal, Assam, Orissa and Madhya Pradesh. Demand for rice is going to increase every year and it is estimated that by year 2025 the requirement would be 140 mt. In India out of total rice, Basmati rice is grown on an area of 2.12 mha producing 8 mt of Basmati rice with an average productivity of 3.77 t/ha. Out of this 8 mt, 4 mt is exported and remaining 4 mt is used for domestic purpose. (Anonymous, 2018).

In India, rice is majorly grown by transplanting the seedlings into puddled soil (land preparation with wet tillage). Puddling benefits rice by reducing water percolation losses, facilitating easy seedling establishment and creating anaerobic conditions to enhance nutrient availability. Puddling greatly controls weeds but repeated puddling adversely affects soil physical properties by destroying soil aggregates, reducing permeability in subsurface layers and forming hard pans at shallow depths (Jat *et al.*, 2009; Naresh *et al.*, 2014), all of which can negatively affect the following non-rice upland crop in rotation (Tripathi *et al.*, 2005). The significantly higher value of soil bulk density after rice harvest under zero tillage plots in the surface soil layer may be due to non-disturbance of the soil matrix, which resulted in less total porosity compared to tilled plots (Bhattacharyya *et al.,* 2008). The disadvantages associated with puddled transplanted rice include the development of a hardpan at a depth of 15–30 cm, and the increased bulk density and soil compaction impair root growth of wheat due to the hardpan (Martinez *et al,* 2008). The higher bulk density under zero or reduced tillage might be due to more compactness of the soil, while the soil became more porous with the increased intensity of tillage in conventional practice (Ram *et al*, 2006). Moreover, puddling and transplanting require large amount of water and labour, both of which are becoming increasingly scarce and expensive thus making rice production less profitable. All these factors demand a major shift from puddle transplanted rice production to unpuddled transplanted rice in irrigated areas. To escape from drudgery in manual transplanting, mechanized rice transplanting is being practiced in many countries of the world but in India mechanized transplanting has not popularized as yet due to high cost of transplanters and land levelling problems.

Raised beds are formed by moving soil from the furrows to the area of the bed, thus raising its surface level. The furrows serve as irrigation channels, drains and traffic lanes. Generally, two to six rows are planted on the top of each bed for rice crop (Naresh *et al.*, 2011). Raised bed dimensions and configurations vary with soil type and available machinery. The ability of the soil to 'sub' (i.e., allow the lateral movement of irrigation water into the centre of the bed) is a key determinant of bed dimensions. For sandy loam soils that sub easily, growers use bed widths at 1.37 m centres for all crop types like rice, wheat. Soils do not sub as well; narrower beds at 0.67 m centres are frequently used. Bed height may also vary with soil conditions and field slope. Higher beds are frequently used on soils that sub well and have flatter grades and longer run lengths, while beds of a lower height are used on steeper graded fields. The flat top of the bed varies from 0.37 to 1.07 m in width. Furrow irrigation used with raised beds requires growers to adopt a whole-farm planning approach to deal with drainage water and the integration of on farm drains and drainage water recycling systems, to increase both, water use efficiency and drainage water quality control (Beecher *et al,* 2005).

Rice is reported to be one of the highly weed invaded crop and is ranked as second highest pesticide consuming crop after cotton. Rice crop suffers from various biotic and abiotic constraints. Weed competition is one of the prime yield-limiting biotic constraints in rice is weeds compete with crops for water, light, nutrients and space. Weeds are the most competitors in their early growth stages than at later stages and hence the growth of crops was suffered and finally reduced the grain yield (Jacob and Syriac, 2005). Weeds grow profusely in the rice field and reduce crop yields drastically normally the loss in yield rangebetween 15 to 20 per cent yet in severe cases the yield losses can be more than 50 per cent, depending upon the species and intensity of weeds. Weed flora under transplanted condition is very much diverse and consists of grasses, sedges and broad-leaved weeds causing yield reduction of rice crop up to 76 per cent (Govindra Singh *et al.,* 2004).The yield of transplanted rice in India is much lower than that of transplanted rice in other rice growing countries. Therefore, proper weed management is essential for satisfactory rice production in India. Weed free period during the critical period of competition is essential for obtaining optimum rice yield. This can be achieved by removing the weeds by mechanical,cultural or chemical means or by their combinations. Herbicidal weed control has been gaining popularity in India in recent years. The main reasons are scarcity of labour during peak growing season, and also lower weeding cost by usingherbicides.Most of the introduced herbicides are selective and are specified to control only one or two types of weeds. Weeds have variable growth habits and life cycles and they even vary under different cultural practices. Therefore, the use of chemicals only cannot effectively control weeds in all situations (De Datta and Herdt, 1983).

Weeds are the major cause of yield reduction in rice. So, weed management is essentially the most important aspect in successful cultivation of rice. Weeds are widely regarded as pests of great agricultural menace as they pose serious problems by causing severe competition with crop plants for nutrients, moisture, solar energy and space. It also causes heavy reductions in growth and yield of crop, which leads to increase in cost of production. Reduction in yield due to weeds is generally proportional to intensity and duration of weed infestation. In India extent of yield reduction in transplanted rice due to weeds alone has been reported to be 10-70%. The loss of yield occurs from 25-30 percent due to unchecked weeds growth (Upadhyay and Gogoi, 1993). The diverse weed flora under transplanted conditions (grasses, sedges and broad-leaved weeds) can cause yield reduction up to 76% (Singh *et al*., 2004). Transplanted rice faces 31% grain yield reduction due to uncontrolled weeds (Rajkhowa *et al.,* 2006). Appropriate control of weeds is thus an important operation influencing rice production. In order to formulate an effective schedule for controlling the weeds in rice crop an understanding of nature and magnitude of competition and their effect on various factors of crop growth becomes an essential pre-requisite. For the age-old practices to control weed is a time consuming and costly. So, the alternative to control weeds is use of herbicides.

The weed flora under transplanted condition is much diverse and consists of grasses, sedges and BLW. Due to germination of weeds in flushes single application of either pre-emergence or post emergence application may not give effective control of weeds and hence need sequential application to ensure weed free condition for longer time. Use of pre and post-emergence herbicides help to keep the crop free of weed at critical stages and maintain better crop growth. The effective control of weeds at initial stages (0-40 DAT) can help in improving productivity of this crop. Use of pre-emergence herbicides such as butachlor, pretilachlor and pendimethalin has been found effective in early stages but the second flush of weeds at later stages has become problematic. In such situations, sequential or mixture application of herbicide is the only alternative, in order to achieve broad spectrum and season long control during the critical period of crop (Gnanavel and Anbhazhagan, 2010).

Effective weed control in transplanted rice is one of the major limitations hindering its wide spread cultivation. Manual removal of weeds is labour intensive tedious, back-breaking and does not ensure weed removal at critical stage of crop weed competition bring heavy reduction in growth and yield of the crop. Hence for transplanted rice, the chemical method of weed management is best suited as take care of weeds right from beginning of crop growth and is cost effective. Most of the herbicides recommended for rice is generally applied as pre-emergence to take care of weed during initial period. However, to have minimum competition between weeds and rice the weeds need to be kept below threshold level, especially during critical weed competition period. Therefore, a new herbicide may be more effective for this purpose. Among all the herbicides for control of *Echinochloa crusgalli,* Bispyribac sodium 25 g a.i./ha was quite good (Yadav *et al*., 2011). Bispyribac-sodium inhibits the plant enzyme acetolactate synthase (ALS), which is involved in biosynthesis of the branched-chain amino acids. The ALS compounds inhibit the production of the amino acid valine, leucine, and isoleucine in plants by binding to the ALS enzyme(Tranel and Wright 2002). Herbicides which give excellent control when applied into water may perform poorly in the absence of standing water (Kumar *et al*., 2009). Bispyribac-sodium is a post emergence herbicide, used as broad spectrum weed control of grasses, broad leaves and annual sedges, with excellent control of *Echinochloa species*. Reduction in weed density due to application of bispyribac-sodium at 15 and 25 DAT in transplanted rice was reported by Yadav *et al*. (2009).

Results of the study revealed that, application of Pretilachlor @ 125% of the recommended dose applied as pre-emergence under continuous flooding provided better weed control efficiency in transplanted Boro rice. But, application of Pretilachlor at recommended dose as pre-emergence under continuous flooding contributed to higher crop dry matter production leading to higher grain yield and harvest index (Ahmed *et al.,* 2014).

The bensulfuron methyl + pretilachlor can effectively manage different categories of weeds, especially of sedge and broad-leaved weeds in transplanted rice field. Bensulfuron methyl 0.6%+ pretilachlor 6% at 60+600 g ha^{-1} suppressed all the predominant weeds throughout crop growing season and recorded higher weed control efficiency, higher grain yield and high herbicide efficiency index. Thus, combined application of bensulfuron methyl 0.6%+ pretilachlor 6% at 60+600 g ha^{-1}at 3 DAT or metsulfuron methyl + chlorimuron-ethyl (Almix) + azimsulfuron at 4+35 g ha^{-1} at 15 DAT may be recommended for broad spectrum weed management and higher paddy yield of wet season rice (Teja*et al.,* 2015). Metsulfuron methyl + Chlorimuron ethyl was effective against control of broad-leaved weeds and sedges (Singh *et al.,* 2003). Pre-emergence application of mixture of almix + 2, 4-D (15 + 500 g ha^{-1}) was most effective against grasses and sedges, when applied at 8 DAT and reduced total weed density and total dry matter with higher weed control efficiency (Mukherjee and Singh, 2005). The performance of metsulfuron methyl + chlorimuron ethyl @ 4 g a.i. ha^{-1} was found superior in controlling *Eclipta prostrata* and provided excellent control of broad-leaved weeds and sedges (Singh and Tewari, 2005).

Keeping these points in view, the present investigation entitled **"Effect of crop establishment methods and weed management options on weed dynamics and performance of**

Basmati rice (*Oryza sativa* L.)" wasconducted at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) during *kharif* season of 2019 and 2020 with the following objectives:

1. To find out the suitable crop establishment method and weed management options for basmati rice
2. To access the weed dynamics and performance of basmati rice under different crop establishment methods and weed management options
3. To estimate the nutrient removal by weed and NPK uptake by crop
4. Economic feasibility of the treatments.

CHAPTER- 2 REVIEW OF LITERATURE

A review of literature on important aspects pertaining to the study entitled**"Effect of crop establishment methods and weed management options on weed dynamics and performance of Basmati rice (*Oryza sativa* L.)"**is being presented in thischapter. The relevant literature collected has been presented under the following heads.

2.1 Effect of crop establishment methods on performance of rice:

2.1.1 Effect of crop establishment methods on growth and development

2.1.2 Effect of crop establishment methods on yield and yield attributes

2.1.3 Effect of crop establishment methods on economics

2.2 Effect of crop establishment methods on weed dynamics

2.3 Effect of weed management practices on performance of rice

2.3.1 Effect of weed management practices on growth and development

2.3.2 Effect of weed management practices on yield and yield attributes

2.3.3 Effect of weed management practices on economics

2.4 Effect of weed management practices on weed dynamics:

2.4.1 Important weed flora in rice crop

2.4.2 Effect of weed management practices on density of weed

2.4.3 Effect of weed management practices on dry matter accumulation by weed

2.4.4 Effect of weed management practices on weed control efficiency

2.5 Interaction effect of crop establishment methods and weed management

2.6 Nutrient uptake by crop

2.7 Nutrient removal by weed

2.1 Effect of crop establishment methods on performance of rice:

2.1.1 Effect of crop establishment methods on growth and development

Singh *et al.* (2002) found that performance of transplanted and direct seeded rice was at par in terms of plant height. Whereas, **Manjunatha*et al.* (2009)** reported that transplanted rice gave higher number of panicles, panicle length, test weight as compared to the direct seeded rice at Agricultural Research Station, Gangavathi, Karnataka.

Kumar *et al.* (2005)reported that the number of effective tillers and 1000-grain weight were maximum under zero-tillage transplant, which were at par withunpuddled and puddle transplant, whereas, the panicle length and number of filled and unfilled grain per panicle were similar under different methods of planting. The grain yield of rice was significantly higher under zero-till transplant compared to FIRBS transplant; however, other treatments were at par.

Yadav *et al.* (2006) reported that the average effective tillers in zero-tillage transplant were high as compared to under conventional system. But plant height and panicle length were similar under both situations.

Kukal *et al.* (2009)reported that among the two establishment methods alternate wetting and drying and transplanting on beds (soil saturation culture), the latter one, i.e., transplanting of rice on beds omits puddling and hence avoids the detrimental effects of puddling.

Sandhu *et al*. (2012) reported that growth parameters like plant height and LAI did not vary with methods of planting. The transplanting of rice in puddled plots resulted in slightly higher root density than raised beds.

Nadeem *et al.* (2012) reported that maximum plant height, leaf area index and dry matter accumulation were more under mechanized rice transplanting followed by conventional transplanting and broad casting of soaked seed methods.

Javaid *et al.* (2012) showed that higher paddy yield was obtained in flat bed sowing method as compared to the raised bed sowing. Flat bed sowing also recorded maximum number of tillers and panicles. Among seeding techniques, conventional transplanting technique had maximum number of tillers and panicles per unit area, spikelets per panicle and paddy yield than other seeding techniques.

Bhuyan *et al.* (2012) observed that the increasing trend of tillers m^{-2} was continued to 50 DAT. At 50 DAT both planting methods*i.e.*, conventional method and bed planting attained the highest number of tiller m^{-2} and then started declining up to 100 DAT. The conventional method produced higher dry matter yield than bed planting. Likewise, at 100 DAT highest dry matter production was also recorded in conventional method than bed planting method.

Hussain *et al.* (2013) tested eight planting methods *viz.* drilling of soaked seed in water condition, drilling on beds and furrow, drilling on beds, planting on beds and furrow, transplanting on beds, line transplanting in a well puddled soil, conventional transplanting and parachute transplanting and observed the highest plant height (123.70 cm) in conventional transplanting.

Chen *et al.*(2014)reported that the response of super rice was greater under transplanted than Direct seeding in wet condition. Grain yield under direct seeding in wet condition was generally lower than transplanted.

Kumhar*et al.* (2016) reported that the highest plant height and dry matter were recorded in wide raised bedstransplanting technique than other methods of establishment *i.e*., direct seeded rice and conventional transplanted rice.

2.1.2 Effect of crop establishment methods on yield and yield attributes

Bajpai and Tripathi (2000) reported that minimum tillage could produce rice yield similar to that under conventional puddling that can be reduced expenses on field preparation.

Prasad *et al.*(2001), Parihar (2004) and Choudhary *et al.*(2004) reported that transplanted rice gave significantly higher grain yield, straw yield, yield attributes than DSR both under puddle and unpuddled conditions. **Singh and Kumar (2005)** reported the lowest rice grain yield under direct seeding as compared to ZT-transplanting, FIRBS-transplanting and puddle transplant.

Bouman and Tuong (2001) and Hauqe*etal.* (2003) revealed that aerobic rice yields to vary from 4.5 to 6.5 t/ha, which is about double than that of traditional upland rice and about 20-30% lower than that of lowland rice grown under flooded conditions.

Singh *et al.* (2005) reported highest grain yield in transplanting, which was in the order of 2.6, 5.2, 6.5, 7.8, 10.4 and 11.7 per cent more than the puddle wet seeding, ZT-transplanting, unpuddled wet seeding, ZT-DSR, bed-DSR, bed-transplanting and dry direct seeding, respectively.

Sayre *et al.* (2005)reported that theyields of rice on permanent beds were always significantly lower than yields of puddled transplanted rice (PTR) on the same soil, and declined to 33–44% of the yield of PTR as the beds aged.

Chandra and Mohan(2006) conducted experiment to compare the productivity of rice cultivation on bed and conventional systems and reported that panicle length, number of grains/panicle, 1000-grain weight and yield of rice increased by 7.06, 4.40, 1.58 and 17.30 %, respectively by bed planting over conventional practices.

Aslam *et al.* (2008)conducted field experiment at Chak 37 and Kot Nazir, Distt. Sheikhupura during 2006 and reported that the highest number of productive tillers/m^2 (231.7) in direct seeding followed by double zero tillage (219/m^2), bed planting (206.7/m^2) and conventional planting (200.2/m^2) respectively. The crop established with double zero tillage produced the highest paddy yield (4.8 t/ha) that was statistically at par with conventionally planted crop (4.72 t/ha).

Saharawat *et al*. (2009) reported that grain yields were higher in unpuddled transplanted rice than in CT-TPR in years 1 and 2. In reduced tillage unpuddled, 60% of the farmers had a yield gain of 0.78 t ha^{-1} over CT-TPR. On average, the highest rice yields (6.5–6.7 t ha^{-1}) were obtained in reduced tillage unpuddled TPR, followed by ZT-TPR.In RT-DSR, yields were 3–8% less than in RT (UP)-TPR, ZT-TPR and CT-TPR.

Mankotia *et al*. (2009) found that among five methods of rice establishment viz. zero tillage, row seeding in prepared bed, broadcast seeding of pre-sprouted seeds in puddle field, row seeding of pre-sprouted seeds with drum seeder and manual transplanting, higher grain yield (3.98 t ha^{-1}) was obtained with transplanting method followed by drum seeding(3.37 t ha^{-1}), broadcast seeding(3.27 t ha^{-1}) of sprouted seeds and row seeding(2.95 t ha^{-1}) in prepared bed**.**

Javaid *et al.* (2012) observed that conventionally transplanted riceproduced significantly higher yield attributes viz. number of spikeletpanicle^{-1}, sterility percentage and grain yield but lower test weightcompared to direct seeded rice method.

Gill and Walia (2014) reported that basmati rice grain yield was significantly higher with machine transplanting after puddling than conventional transplanting of basmati rice but was statistically at par with direct seeded basmati rice with brown manuring.

Jat *et al.* (2014) reported that during initial three years of experimentation higher rice grain yield in conventional puddled transplanted. While in the fourth and fifth years, the rice yields under conventional tillage and conservation tillage were comparable whereas sixth year onwards, higher yields were recorded under conservation tillage than in conventional tillage.

Naresh *et al*. (2014) reported that rice yields in zero till transplanted rice (ZT-TPR), reduced till transplanted rice (RT-TPR) and transplanted rice on wide raised beds (WBed-TPR) were on at par with conventional till transplanted rice**(**CT-TPR). On an average, the highest rice yields (5.76, 5.53, 5.33 and 5.13 t/hm^2) were obtained in CT-TPR, followed by ZT-TPR, WBed-TPR and RT-TPR.

Parameswari and Srinivas (2017) conducted an experiment to study the effect of establishment methods on growth and yield of rice at ANGRAU (Hyderabad) and reported that among different establishment methodsi.e., direct sowing of sprouted seeds under puddled condition, SRI and transplanting, transplanting of rice recorded significantly higher grain and straw yield.

Rahman *et al.*(2019) reported that the highest grainyield (5.54 t/ha) and harvest index (46.69%) was obtained in puddled transplanting method due to the higher production of effective tillers perhill and the higher number of grains per panicle compared to DSR,unpuddled transplanting and AWD (Alternate wetting and drying).

2.1.3 Effect of crop establishment methods on economics

Gill *et al*. (2006) reported that puddled condition of soil requires large amounts of labour, water and energy, which are gradually becoming scarce and more expensive and reducing the profitability and system sustainability.

Sanjay *et al*. (2006a) stated that linetransplanting recorded significantly higher grossincome (Rs.31,158 ha^{-1}) compared to drum seeding(Rs. 30,829 $ha^{-1)}$ and broad cast seeding (Rs. 22,032ha^{-1}).

Gupta and Sayre (2007) reported that raised bed planting has shown saving of 55%, 42%, and 44% in time, energy and cost of operation over conventional system on fresh beds, whereas, on permanent beds, these values are 63%, 56% and 57%, respectively.

Ladha *et al.* (2009) reported that in reduced-till unpuddled fields, transplanting (RT-TPR) was more productive and profitable than drill seeding of rice (RT-DSR), he also reported that Transplanting of rice on raised beds (Bed-TPR) reduced mean grain yield and net income, whereas zero-till (ZT-TPR) or reduced-till transplanting (RT-TPR) increased rice yield.

Hussain *et al.* (2013) tested eight planting methods viz. drilling of soaked seed in water condition, drilling on beds and furrow, drilling on beds, Planting on beds & furrow, transplanting on beds, line transplanting in a well puddled soil, conventional transplanting and parachute transplanting. The highest profit (Rs. 10898 ha^{-1}) and cost benefit ratio (1.29) were observed in line transplanting method followed by conventional transplanting method.

Chakraborty *et al.*(2017)reported that Conventional transplanting system (TPR) of ricecrop production requires labour, water, capital, and energy in largeamount so that it has become less profitable at present due to the lack ofthese resources.

Bhardwaj *et al.* (2018) conducted an experiment at Birsa Agricultural University, Ranchi, Jharkhand to study the effect of different crop establishment methods on weed dynamics, productivity and economics of rice and reported that the rice crop established by conventional transplanting had similar net return with drum seeding of sprouted seeds methods.

Naz *et al*. (2020)conducted an experiment at the Research Farm of Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar to investigate the effect of crop establishment methods and weed management practices on productivity, economics and nutrient uptake in direct seeded rice and reported that, puddled condition recorded maximum gross and net returns with a B:C ratio of 1.25 and was found significantly superior over zero-tillage and dry-seeding.

2.2 Effect of crop establishment methods on weed dynamics

Singh *et al.* (2005) conducted an experiment conducted at Sugarcane Research Station, Kashipur, G. B. Pant University of Agriculture & Technology, Pantnagar, U.S. Nagar (Uttaranchal) to study the effect of crop establishment methods on weed dynamics in rice and reported that the maximum reduction of weed species was obtained under transplanted rice.

Subbalakshmi and Pandian (2009) reportedthat weed density was lower in transplanted rice as compared to line sowing and broadcasting of seeds because, first flush of weeds was incorporated in the soil during the field preparation for transplanting which resulted in less crop-weed competition.

Punia *et al.* (2016)conducted an experiment at the farm of a farmer in Haryana to know the long-term impact of crop establishment methods on weed dynamics in rice-wheat cropping system and reported that the weed dynamics after 4 years revealed that in rice crop, weed density of *Echinochloa colona, E. crusgalli, Leptochloa chinensis, Cyperus spp.* and broad-leaf weeds such as *Ammania baccifera* and *Eclipta alba* was more when rice was transplanted under zero tillage conditions.

Bhardwaj *et al.* (2018) conducted an experimentconducted an experiment at Birsa Agricultural University, Ranchi, Jharkhand to study the effect of different crop establishment methods on weed dynamics in rice and reported that conventionally puddled transplanted rice had significantly lower weed density (29.4%).

2.3 Effect of weed management practices on performance of rice

2.3.1 Effect of weed management practices on growth and development

Subhalakshmi and Ramana (2008) concluded that the growth parameters *i.e.,*plant height, number of tillers m^{-2} and dry matter production were higher in hand weeding at 20 and 40 DAT irrespective of the crop.

Yadav *et al.* (2009) conducted an experiment at CCSHAU Regional Research Station, Karnal, Haryana and observed that application of Bispyribac @ 15 and 20 g a.i./ha as post-emergence, recorded the highest plant height (92.3 cm).The herbicide application proved to be better than weed free treatment which was recorded the plant height was 88.9 cm.

Gnanavel and Anbhazhagan (2010) noticed that the pre-emergence application of oxyfluorfen @ 0.25 kg ha^{-1} followed by post-emergence application of bispyribac sodium @ 0.05 kg + metsulfuron methyl @ 0.01 kg ha^{-1}was effective and significantly superior to the 25 rest of treatments by recording highest plant height (105.82), number of productive tillers (308.32 m^{-2}), and grain yield (5.32 t ha^{-1}).

Parthipan (2013) reported that taller plants (123.8 and 125.1 cm) with higher leaf area index (6.55 and 6.50) were recorded by two hand weedings fb POE application of bispyribac sodium 25 g ha^{-1} supplemented with one HW during both years. Increase in plant height and leaf area index might be due to better environment with increased uptake of both macro and micro nutrients by rice due to reduced crop weed competition.

Dubey*et al.*(2017)concluded that maximum shoot dry matter, higher number of panicles, grains per panicle, panicle length, test weight, and grain yield was recorded in hand weeding (20 and 40 DAS/DAT) than that of other weed management practices.

2.3.2 Effect of weed management practices on yield and yield attributes

Bhowmik *et al.*(2000) found that pretilachlor at 0.8 kg ha^{-1} effectively controlled the weeds in transplanted rice and recorded the maximum grain and straw yields which were at par with hand weeding.

Halder and Patra (2007) concluded that application of AlmixTM 0.004 kg + butachlor 1.0 kg ha-1 and butachlor 1.0 kg ha^{-1}, followed by AlmixTM 0.004 kg ha^{-1} increased the grain yield by 36.8 and 33.6 %, respectively, over the unweeded check.

Deepa and Jayakumar (2008) reported that the grain yield of rice was significantly influenced by the weed control treatments over unweeded control. The highest grain yield of 5737 and 5822 kg ha^{-1} were obtained with pretilachlor at 1.0 kg ha^{-1} during *rabi* and summer respectively. The most important factors deciding the grain yield *viz.*, panicles m^{-2} (no.), panicle length, grains $panicle^{-1}$ and test weight were the highest in pretilachlor at 1.0 kg ha^{-1}.

Yadav *et al*. (2009) reported that 37-41% increase in the grain yield of rice over weedy check with the application of Bispyribac @ 25 g ha^{-1} applied at 15-25 DAT and found to a suitable herbicide for 24 complex weed flora in transplanted rice.

Kenchaiah *et al*. (2009) reported that application of recommended herbicide pretilachlor + safener 0.4 kg ha^{-1} applied at 3 DAS recorded maximum grain yield (4.43 t ha^{-1}) which was on par with tank mix application of clomazone + propanil 750 mL ha^{-1} at 20 days after sowing with grain yield of 4.19 t ha^{-1}.

Pal *et al*. (2009) opined that hand weeding on 20 and 40 DAT recorded highest grain yield of 5.08 t ha^{-1} in Gangetic alluvial soil because it gave little scope to weeds to flourish and to compete with the crop preferably at the critical stage of crop weed competition.

Sangeetha*et al.* (2009) concluded that pre-emergence application of pretilachlor through starch formulation at 5 kg ha^{-1} was found to be effective in controlling weeds and thereby increasing the growth and yield of rice.

Rao *et al.* (2009) reported that the application of bispyribac sodium @ 30 g a.i. ha^{-1} recorded 5431 and 5979 kg ha^{-1} of grain yield during *kharif* and *rabi* seasons, respectively, which were comparable with two hand weedings and standard check pretilachlor during both the seasons.

Suganthi*et al*. (2010) reported that pre-emergence application of pretilachlor at 1.0 kg ha^{-1} and pretilachlor at 0.75 kg ha^{-1} with one hand weeding at 45 DAT offered better weed control and resulted in increased yield of transplanted rice compared to the recommended weed control methods of butachlor @ 1.25 kg ha^{-1}, anilofos @ 0.4 kg ha^{-1} and hand weeding twice.

Singh and Singh (2010) concluded that weed control treatments showed marked improvement in grain yield. The maximum grain yield (4.73 t ha^{-1}) was recorded under pretilachlor followed by 2,4-D which was on par with hand weeding treatments (4.87 t ha^{-1}) and pendimethalin followed by 2,4-D which had grain yield of 4.59 t ha^{-1}.

Ali *et al*. (2014)concluded that number of productive tillers m^{-2}were also higher with twice application of bispyribac sodium than other herbicidal treatments and weedy check. Highest number of filled grains $panicle^{-1}$ (116.3) and lowest number of filled grains $panicle^{-1}$(43.6) were recorded with application of bispyribac sodium than other herbicidal treatments and weedy check.

Parthipanand Ravi (2016) found that post emergence application of bispyribac sodium at 25 g ai ha^{-1} at 15 DAT followed by hand weeding at 45 DAT produced higher grain yield and was at par with two hand weedings due to lower crop weed competition.

Nivetha*et al.* (2017) conducted experiment in Tamil Nadu during *rabi* 2016-2017 to evaluate the weed management practices in transplanted rice under sodic soil and reported that pre-emergence application of bensulfuron methyl + pretilachlor @ 60 + 600 g a.i. ha^{-1} at 3 DAT *fb*hand weeding at 40 DAT recorded significantly higher grain and straw yield.

Mekonnen*et al.* (2018) conducted experiment in Bench Maji Zone at GuraferdaWoreda, during the 2017 and reported that significantly higher grain yield of 4776.5 kg $ha^{-1}$was produced with the application of Bispyribac-sodium @ 20 g ha^{-1} + hand weeding and hoeing at 35 DAE.

Kumar *etal.*(2018)concluded that Manual weeding thrice (20, 40 and 60 days) and Pretilachlor @ 750gha^{-1} at 0-2DASfbAlmix @ 4 g ha^{-1} at 25DAS (3-4 Leaf stage of rice crop) recorded significantly higher values of grain and straw yield as compared to bispyribac-Na @ 25g ha^{-1} at 30 days stage alone and weedy check.

Kalaisudarson (2019)recorded significantly highest number of panicles m^{-2} (348) with the application of pre-emergence herbicide bensulfuronmethyl+ pretilachlor 0.66 kg ha^{-1} on 3 DAT followed by post emergence herbicide bispyribac sodium 0.02 kgha^{-1}on 30 DAT. Unweeded control recorded thelowest number of panicles m^{-2} of (228). The better performance of this treatment could be attributed toefficient control of weeds. Further, enhanced crop vigour due to better nutrient mobility leads to produce morenumber of panicles.

2.3.3 Effect of weed management practices on economics

Sharma and Upadhyay (2002) reported that Pretilachlor 625 g ha^{-1} was more economical as compared to butachlor 1250 g ha^{-1} getting good yield as well as cost benefit ratio.

Mukherjee and Singh (2005) found superiority in net monetary returns with the appliances of chlorimuron-ethyl + metsulfuron-methyl + 2, 4-D for transplanted rice over other weed control means.

Hussain *et al.* (2008)reported that highest net benefit was obtained by the application of bispyribac sodium 100 SC followed by Ethoxysulfuron 60 WG treatments while the lowest net benefit was provided by control (weedy check). NO doubt, the result of hand weeding is significantly better as it is time consuming and laborious hence cannot be recommended at large scale.

Pal *et al*. (2009) reported that application of Almix 20 WP @ 4g ha^{-1} as post emergence herbicide at 15 DAT in transplanted rice resulted in highest BCR of 1.41 and maximum net return of Rs. 21, 802 in comparison to hand weeding.

Singh and Singh (2010) emphasized that net returns and BCR were maximum with pretilachlor followed by 2,4-D. The higher net return and BCR under these treatments was owing to more grain yield and comparatively low cost of pretilachlor as compared to other pre-mergence herbicides.

Kiran *et al.* (2010) conducted an experiment to know the economics of weed management in rice and concluded that sequential application of bispyribac-sodium @ 30 g ha^{-1} recorded the highest net returns and highest benefit cost ratio.

Veeraputhiarn and Balasubramanian (2010) reported that the post emergence application of bispyribac sodium at 25 g ha^{-1} registered a highest net profit of Rs.42, 452ha^{-1} and highest B: C ratio of 2.89 was recorded.

Saha *et al.* (2012) reported that the application of almix *fb* 2, 4-DEE (0.025 *fb* 0.5 kg ha^{-1}) gave the highest net returns (Rs. 18070/ha) and benefit: cost ratio (1.99) than two hand weddings although, significantly reduced weed density and their biomass and increased the grain yield, owing to higher labour cost reduced the benefit: cost ratio.

Prameelaet al. (2014) reported that the economics of rice cultivation shows that for high returns (Rs. 67,090) and B: C ratio (1.8), spraying cyhalofop-butyl followed by Almix is the best. The treatments fenoxaprop p-ethyl *fb* Almix and bispyribac sodium also gave a B: C ratio of 1.8. Although the yield was a little lower in bispyribac sodium, as the cost of cultivation was low due to one-time application of herbicide, it could maintain high B: C ratio of 1.8. However, the grain yield of 5.73 Kg ha^{-1}, obtained with bispyribac sodium was statistically on par with cyhalofopbutyl *fb* almix and fenoxaprop p-ethyl *fs* almix (5.8 Kg ha^{-1}).

Parameswari andSrinivas (2017) conducted experiment and reported that, among different weed management practices, higher gross returns and net returns were recorded with farmer's practice however, bensulfuron methyl + pretilachlor mixture @ 60 + 600 g a.i. ha^{-1} followed by mechanical weeding at 30 DAT resulted in higher B:C ratio.

Nivetha *et al. (*2017) revealed that pre-emergence application of bensulfuron methyl + pretilachlor at 60 + 600 g a.i. ha^{-1}on 3 DAT followed by hand weeding on 40 DAT gave highest net returns (Rs. 47765 ha^{-1}) and B: C ratio (2.49) was realized compared to that weed free check (Rs. 42640 ha^{-1}) and B: C ratio (2.25).

Naz *et al*. (2020)conducted an experiment at the Research Farm of Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar and reported that two hand weedings at 20 and 40 DAS had the highest gross return followed by Pretilachlor @ 1.50 kg ha^{-1}(PE) *fb* one hand weeding at 30 DAS.

2.4 Effect of weed management practices on weed dynamics

2.4.1 Important weed flora

Avudaithai and Veerabadran (2000) reported that proportion of grasses, sedges and broadleaved weeds was 55, 16 and 29 per cent, respectively with *Echinochloa colona* and *Cyperus iria* as dominating weeds in transplanted rice at Madurai (Tamilnadu).

Sarkar (2001) reported *Echinochloa crus-galli, Paspalum distichum* and *Caesulia axillaris* as the major weed species in transplanted rice accounted 20.92, 18.30 and 16.54 per cent, respectively of total weed population at Pantnagar (Uttarakhand).

Bhanu Rekha *et al.* (2002) found that **t**he major weed flora associated with rice on clay loam soils of Hyderabad were grasses like *Echinocloa colona*, *Panicum repens* and *Paspalum distichum;* sedges like *Cyperus difformis, Cyperus iria, Scirpus supinus* and *Fimbristylis dichotoma;* broad leaf weeds *viz., Ammania baccifera, Caesulia axillaris, Eclipta alba and* Marseliaminuta.

Saha (2006) noted from Cuttack (Orissa) that *Echinochloa colona, Cyperus difformis, Fimbristylis miliacea, Sphenochlea zeylanica* and *Ludgwigia parviflora* were the pre-dominant weed species in wet direct-sown summer rice. Thus, grasses constituted (9.5%), sedges (57.2%) and broadleaf weeds (33.3%) of the total weed population at 30 days stage.

Mann *et al.* (2007) reported that *Echinochloa crus-galli, Cyperus iria, Cyperus difformis, Paspalum distichum, Eclipta prostrata* and *Trianthema portulacastrum* were the major weeds associated with dry seeded rice at Punjab (Pakistan).

Hussain *et al.* (2008) also reported *Echinochloa crusgalli, Leptochloa chinensis,Cyperus iria, Fimbristylis miliacea, Ludwigia parviflora, Lindernia crustacean and Monochoria vaginalis* as the major weeds of wet seeded rice. According to

Puniya *et al.* (2009)the major weed species that infested the rice crop were *Echinochloa colona, Caesulia axillaris* and *Commelina benghalensis*. Sedges (*Cypers* *difformis Fimbristylis miliaceae, Cyperus iria* and *Scirpus spp*.) constituted the highest percentage of total weed density.

Yadav *et al.* (2009) found that *Echinochloa glabrescens* and *E. colona* (L.) Link among grasses, *Ammannia baccifera* L. and *Euphorbia spp*. among broadleaf weeds and *Fimbristylis miliacea* (L.), *Cyperus iria* L., *Cyperus rotundus* L. and *Cyperus difformis* L. among sedges were the major weeds of transplanted rice at Karnal, Haryana.

Jayadeva (2010) stated that *Echinochloa spp.* among grasses *Cyperus rotundus, Scripus royali* and *Fimbristylis miliaceae* among sedges, *Ludwigia parviflora, Lindernia veronicaefolia* and *Glinus oppostifolia* among the broad-leaved weeds were the dominant weed flora during both *kharif* and summer.

Hossain *et al.* (2010) observed that *Fimbristylis miliacea, Ludwigia parviflora, Sphenoclea zeylanica* and *Lindernia crustacea* were the predominant weeds under different rice establishment techniques *viz*., SRI, transplanted rice, broadcast sprouted seed and drum seeded rice at Sriniketan (WB).

Ahmed and Bhuiyan (2010) reported grassy weeds were dominant in direct wet seeded rice whereas sedges and broad leaf weeds were dominant in transplanting method of rice. Weed control efficiency varied from 80 to 85 per cent against different weed control treatments. Weed number and weight was significantly higher in broadcast and drum seeded method resulting in lower weed control efficiency than transplanting method. Higher panicles m^{-2} in broadcasting and drum seeded method led to higher grain yield than transplanting method. Broadcasting and drum seeding method produced lower grain yield in unweeded condition as compared to transplanting method under same condition.

Rahman *et al*. (2012) reported that in the dry season, the lowest weed densities of 40 and 21 weeds m^{-2} were registered at 30 and 60 DAS with cyhalofop-butyl + bensulfuron fb bentazon/MAPA, while at 75 DAS, the lowest one (11 weeds m^{-2}) was found with Pendimethalin *fb*Bentazon/MAPA. In the wet season, the lowest total weed density at 30 DAS was recorded with pretilachlor *fb* bentazon/MAPA while at 60 and 75 DAS, pendimethalin *fb*cyhalofop-butyl + bensulfuron *fb*bentazon/MAPA allowed least weed density (80 and 80 weeds m^{-2}, respectively).

Ramachandiran *et al.* (2012) reported that at Madurai the predominant category of weed was broad leaved weeds followed by grasses and sedges in aerobic rice. The weed flora mainly consisted of *Echinochloa colonum, Panicum javanicum, Chloris barbata, Dactylocteninum aegyptium* and *Panicum repens* under grasses, *Cyperus iria* under sedges and *Cleome viscosa, Corchorus olitorius, Euphorbia hirta, Merremiaemarginata, Portulaca oleracea* and *Trianthema portulacastrum* under broad leaved.

Manjunatha *et al.* (2013) summarized that dominant weed flora in transplanted rice as grassy weeds like *Echinochloa colona, Panicum repens,* sedges like *Cyperus difformis, Cyperus procerus, Euriocolon spp.,* and broad-leaved weeds *like Monochoria vaginalis, Ammania baccifera, Rotala verticillaris, Ludwigia parviflora* and *Marselia quadrifoliata* in the sandy loam soils of Karnataka during *kharif* season.

Borah *et al.* (2014) stated that weed population in the experimental field consists of *Alternanthera philoxeroides, Cuphea balsamona, Eichhornia crassipes, Hydrolea zeylanica, Marsilea minuta, Spenochlea zeylanica* and *Spilanthespaniculata* among broad leaved weeds, *Echinochloa crus-galli* and *Sacciolepisinterrupta* among grasses *Scirpus juncoides* was the sedge at Assam.

Sundari (2014) stated that *Echinochloa colona* (22.7%), L. *chinensis* (24.63%), *C. rotundus* (19.99%) and *M. quardrifoliata* (32.68%) constitutes the major weed flora under transplanted condition at Tamil Nadu.

Khare *et al.* (2014) observed that the dominant weed flora in the present experiment comprised of *Echinochloa colona*, *Echinochloa crusgalli*, *Leptochloa chinensis*, *Eclipta alba* and *Cyperus difformis. Echinochloa crusgalli* (28-30%) was the predominant weed in direct seeding and transplanted methods of rice culture, whereas the lower density (10-12%) was recorded of *Cyperus difformis* indicating its effective control in both methods of rice culture.

Malviya *et al.* (2014) reported that the most common weed-flora observed in aerobic rice experimental field were *Paspalum spp., Setania spp., Cynodon dactylon, Echinochloa colonum, Panicum spp.,* as grass weeds, *Cyperus rotundus* and *Cyperus esculentus* as sedges and *Digeria arvensis, Anagalis arvensis, Convolvulus arvensis, Celosia argentia, Eclipta alba and Euphorbia hirta* as broad-leaved weeds.

Nikhil and Singh (2014) reported that experimental field was infested with grassy (*Echinochloa colona*, *E. crusgalli*, *Paspalum spp*., *Cynodon dactylon*), sedges (*Cyperus rotundus* and C*yperus iria*), and broad-leaved weed (*Caexulia auxillaries*). Among the weed flora the maximum relative percentage was of *Echinochloa colona* (23.8, 24.5 and 23.4%), *Echinochloa crusgalli* (23.4, 24.0 and 22.9%), *Cyperus rotundus* (16.1, 15.7 and 16.2%) and *Caesulia axillaries* (7.8, 6.8 and 8.2%) in zero-till DSR, zero-till DSR with anchored residue and reduced till, respectively.

Parameswari *et al.* (2014) reported that the total weed density was higher (43.49 plants m^{-2}) under direct seeded rice (sprouted seeds) under puddle condition compared to transplanting (33.73 plants m^{-2}) and SRI (37.67 plants m^{-2}) which might be due to failure to maintain flooded conditions in field and non-submergence of crop in the initial stages, crop and weeds germinate simultaneously so competition exists.

Singh *et al.* (2014) conducted an on-farm trail in *kharif* 2013 at five farmers' fields of Almora district and stated that dominant weed flora observed during the trail were *Echinochloa colona, Echinochloa crus-galli, Digitaria sanguinalis, Oxalis latifolia, Commelina benghalensis* and *Ageratum conizoids* etc.

Joshi *et al.* (2015) noticed that major weed flora present in the rice experimental field included *Echinochloa crusgalli* (15.8%), *Ecinochloa colona* (23.8%), *Leptochloa chinensis* (18.4%), *Ammania baccifera* (14.8%), *Caesulia axillaris* (10.3%), *Cyperus rotundus* (8.9%) and others (8.7%) in rice crop.

Yakadri*et al. (*2016) observed thatmajor weed flora in transplanted rice comprised of *Echinochloa colona*, *Echinochloa crusgalli*, *Eclipta alba*, *Commelina bengalensis*,*Celosiaspp*., *Ammania baccifera*, *Panicum repens*, *Bacopa monneri*and *Cyperus difformis*, *Cyperus spp.*, *Scirpus supinus*,*Cyperus rotundus*, *Cyperus iria*. During rainy season the weed flora recorded under puddled consisted of 52.8% grassy weeds, 24.2% sedges and 22.9% broad-leaf weeds of the total weed population.

2.4.2 Effect of weed management practices on density of weed

Bhanu Rekha *et al.* (2002) reported that hand weeding twice at 20 and 40 DAT resulted in significantly lower weed density and dry weight as compared to herbicide treatment and un-weeded check.

Kathirvelan and Vaiyapuri (2003) conducted field experiment and reported that pre-emergence application of pretilachlor @ 300 g a.i. ha^{-1} followed by 2, 4-D @ 300 g a.i. ha^{-1} recorded the lowest weed density (11.3m^{-2}) in transplanted rice.

Mishra and Singh (2007) opined that pre-emergence application of Pretilachlor @ 750gha^{-1} followed by one hand weeding at 30 DAS significantly reduced the weed population compared to weedy check during kharif season.

Gopinath and Kundu (2008) found that Sequential application of butachlor two days after sowing and metsulfuron methyl + chlorimuron-ethyl 21 DAS recorded significantly lower density of weeds.

Sangeetha*et al.* (2009) concluded that pre-emergence application of pretilachlor + safener @ 0.45 kg ha^{-1}followed by hand weeding at 45 DAS resulted in lower total weed density and increased grain yield in direct seeded rice.

Prakash *et al.* (2017) conducted field experiment at the Crop Research Centre of S.V.P. University of Agriculture & Technology, Meerut, to evolve weed management practices in rice and concluded that the reduction in total weed density was recorded 79.74 percent with the application of Pretilachlor *fb* Almix and 89.60 percent with two hand weeding over weedy check.

Yadav *et al.* (2017)reported that maximum reduction in weed density and dry matter accumulation was recorded with pre-emergence application of pretilachlor 750 g ha^{-1} without water stagnation in field up to one week fb post emergence application of bispyribac-Na 20 g ha^{-1} and post-emergence application of bispyribac-Na 20 g ha^{-1} at 60 DAT was most effective in controlling mixed population of the weed flora. Their effectiveness was at par with twice hand weeding.

2.4.3 Effect of weed management practices on dry matter accumulation by weed

Chander and Pandey(2001) registeredsignificantly lower weed dry weight in transplantedrice than in direct seeded rice at tillering, floweringand maturity stages.

Prasad *et al*. (2001) stated that transplanting recorded the lowest weed population (63.5 m^{-2}) and weed dry weight (24.1 gm^{-2}) which was followed by sowing of sprouted seeds in puddle condition and dry drilling seeds.

Walia *et al.* (2008) conducted an experiment in Ludhiana, Punjab and noticed that post-emergence application of bispyribac sodium @ 30 g a.i. ha^{-1} (10.78 q ha^{-1}), Penoxsulam @ 20 g a.i. ha^{-1} (14.30 q ha^{-1}) significantly reduced weed dry weight (5.50 q ha^{-1}), which was superior to other (post-emergence) azimsulfuron 25 g a.i. ha^{-1}at (11.29 q ha^{-1}).

Singh *et al*. (2008)reported thatthe herbicides (pretilachlor, butachlor and pendimethalin) also reduced the total weeds dry weight over control treatment (weedy check) very effectively (73.7 to 86.8%) which represents their weed control efficiency.

Lakshmi *et al*. (2009) concluded that supplementation of hand weeding at 20 DAS to pre-emergence herbicides were found to be superior in reducing weed density and weed dry matter.

Veeraputhiran and Balasubramanian (2010)conducted an experiment reported that the application of bispyribac sodium @ 25, 35, 50 g a.i. ha^{-1} resulted in the reduced total dry weight accumulation by weed than butachlor application, hand weeding twice and unweeded check.

Kumar*et al.* (2018)conducted an experiment at Agronomy Research Farm of Narendra Deva University of Agriculture &Technology, Kumarganj, Faizabad (U.P.) during

*Kharif*season of 2015 and 2016 and reported that dry matter accumulation was influenced at all the crop growth stage due to various weed management practices. Manual weeding thrice (20, 40 and 60 DAT) and application of Pretilachlor @ 750g ha^{-1} at 0-2 DAT *fb* Almix @ 4 g ha^{-1} at 25 DAT being at par recorded significantly more dry matter accumulation over bispyribac-Na 25g ha^{-1} as post emergence application alone and weedy check treatments, except 30 DAS stage.

2.4.4 Effect of weed management practices on weed control efficiency

Ravisankar *et al*. (2008) noticed that the pre-emergence application of pretilachlor plus @ 0.30 kg ha^{-1} at 2DAS + hand weeding at 45 DAS registered lower weed density and higher weed control efficiency.

Ramana *et al.* (2007) reported that pre-emergence application of metsulfuron methyl 10% + chlorimuron ethyl 10% @ 6.0 g ha^{-1} resulted in better weed control efficiency but the improved efficacy could not be translated to better yield due to its phytotoxicity on rice.

Saha and Rao (2010)reported that among the tested herbicides, metsulfuron methyl 8 g/ha applied 10 days after transplanting was found to be the most effective herbicide (weed control efficiency 87.9%) in controlling the pre-dominant weeds.

Revathi *et al.* (2010) concluded that highest weed control efficiency is recorded by application of bispyribac sodium PE fb fenoxaprop-p-ethyl + 2, 4-D at all the stages of crop.

Shultana *et al.* (2011)recorded lowest weed biomass and significantly highest weed control efficiency (86.01%) with the application of pretilachlor 50 EC at 1 lit ha^{-1} under Gazipur, Bangladesh situation.

Prakash*et al.*(2017) reported that application of bispyribac+almix at 60 DAT found to have significantly lower total weed dry weight (4.19 and 3.61), total weed density (5.38 and 4.84) and significantly higher weed control efficiency (84.83 and 87.08 %).

Chinnamani*et al.* (2018) reported that the application of pretilachlor @ 0.75 kg a.i. ha^{-1} as PE *fb* bispyribac sodium @ 25 g a.i. ha^{-1} at 20 DAS as Early Post Emergence (EPoE) recorded significantly lowest total weed density and highest weed control efficiency.

Sangra *et al.* (2018) reported that the highest weed control efficiency (91.48) was recorded from bispyribac sodium salt @ 250 ml *a.i.* ha^{-1} POE at 15 DAS + One hand weeding at 30 DAS (W8) followed by two hand weeding at 15 and 30 DAS.

2.5 Interaction effect of crop establishment methods and weed management

Mohapatra*et al.* (2012)conducted an experiment and reported that the machine planting with mechanical weeding encouragesprofuse tillering which increases the number of panicle/m^2 and number of grains per panicle and grain yield.

Parameswari and Srinivas (2017) concluded that none of the growth characters and yield attributes was markedly influenced by interaction effects of crop establishment methods and weed management practices. Similarly grain and straw yields were also not influenced by interaction effects between crop establishment methods and weed management practices.

Subramanyam *et al.* (2007)reported thatin the early stage of crop growth if heavy infestation of weeds occurs and left uncontrolled, the submergence later on will not effective in controlling weeds. Continuous submergence of the crop effectively suppressed the weed population and weed seed germination under transplanted rice.

2.6 Nutrient uptake by crop

Bhuyan *et al.* (2012) conducted an experiment and found that agronomic efficiency (AE) of nitrogen fertilizer in raised bed was 32.15% which was significantly higher than the conventional plot(27%). The AE in raised bed was 20% higher than conventional plot.

Naresh *et al.* (2014) reported that the maximum uptake of total N was recorded in WBed-TPR, which was significantly higher over all other treatments except CT-TPR and ZT-TPR. The total K uptake by the crop though at par under the planting techniques, WBed-TPR and CT-TPR, significantly higher over the rest of the treatments. The higher amount of nutrient uptake under wide raised bed planting techniques was associated with higher biomass accumulation under these treatments, which led to higher amount of uptake of these nutrients.

Kanthi*et al.* (2014) stated that the uptake of nitrogen, phosphorus and potassium by rice at flowering and harvest stage was found to be the maximum with transplanting method which was comparable with semi- dry system.

2.7 Nutrient removal by weed

Sanjay *et al*. (2006b)reported that Nutrient removal by weeds in broadcast sowing method (12.1, 2.4, and 19.5 N, P and K kg ha^{-1}) was significantly higher compared to line transplanting method (9.2, 1.8 and 15.1 kg ha^{-1} N, P and K respectively).

Puniya*et al*. (2007) conducted an experiment during *kharif* in silt loam soil of Pantnagar and noticed that the highest loss of nutrients (42.07 kg N, 10.00 kg P and 21.80 kg K ha^{-1}) occurred with unweeded control due to more density and dry weight of weeds in transplanted rice.

Mukherjee and Maity (2011) reported that the herbicide application and hand weeding almost completely controlled the weed which leads to less removal of nutrient by the weed and more by the crop as compared to unweeded control whereas, in complete weedy situation weeds removed 30.1 to 34.3 kg N, 5.8 to 7.4 kg P and 37.8 to 42.9 kg K ha^{-1}in transplanted rice.

Devi and Singh (2016) conducted an experiment to evaluate the effect of weed management practices on drymatter accumulation and nutrient removal by weed in rice cropand reported that the hand weeding twice at 20 and 40 DAS followed by bispyribac at 25 g a.i. ha^{-1} + azimsulfuron at 17.5 g a.i. ha^{-1}+ NIS (0.25 %) at 15-20 DAS proved most effective practice and resulted in reduced nutrient removal by weeds as compared to other herbicidal treatments.

Verma *et al.* (2017) conducted an experiment to assess the efficacy of different weed management practices on weed dynamics, nutrient removal and productivity of basmati rice in rice-wheat cropping system and reported that the most efficient weed control was provided by the application of Pendimethalin @ 1.0 kg ha^{-1} (PE) *fb*Bispyribac @ 0.030 kg ha^{-1} (PoE) that resulted in minimum removal of nutrients by weeds.

Rathod and Somasundaram (2017) conducted an experiment to assess the nutrient uptake by weeds and crops under different organic weed management practices and reported that the minimum depletion of N, P and K by weeds was observed in unweeded check.

CHAPTER - 3 METHODS AND MATERIALS

The field experiment was conducted to study the "Effect of crop establishment methods and weed management options on weed dynamics and performance of Basmati rice (*Oryza sativa* L.)" during *kharif* season of 2019 and 2020 at Crop Research Center of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut. The details of procedure followed, criteria used for treatment evaluation and method adopted during entire investigation are prescribed in this chapter.

3.1 Experimental Site and Location

The field experiment was conducted at Crop Research Center of Sardar Vallabhbhai Patel University of Agriculture &Technology, Meerut (U.P.), located at latitude of 29^0 04′ North and longitude of 77^0 42′ East with an elevation of 228 meters above the mean sea level. The Meerut area lies in the heart of Western Uttar Pradesh and has sub-tropical climate. The experimental site has an even topography with good drainage system in the farm.

3.2 Climate and Weather Condition

The data on climatic parameters such as rainfall (mm), mean maximum and minimum temperature, evaporation, air velocity and relative humidity recorded at meteorological observatory, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) for the year 2019 and 2020.

The climate of this region is characterized as semi-arid and sub-tropical. The summer is very hot and dry while winters are too cold. Moderate rainfall and wide temperature variation are the characteristic features of the semi-arid and sub-tropical climate. Generally, South-West

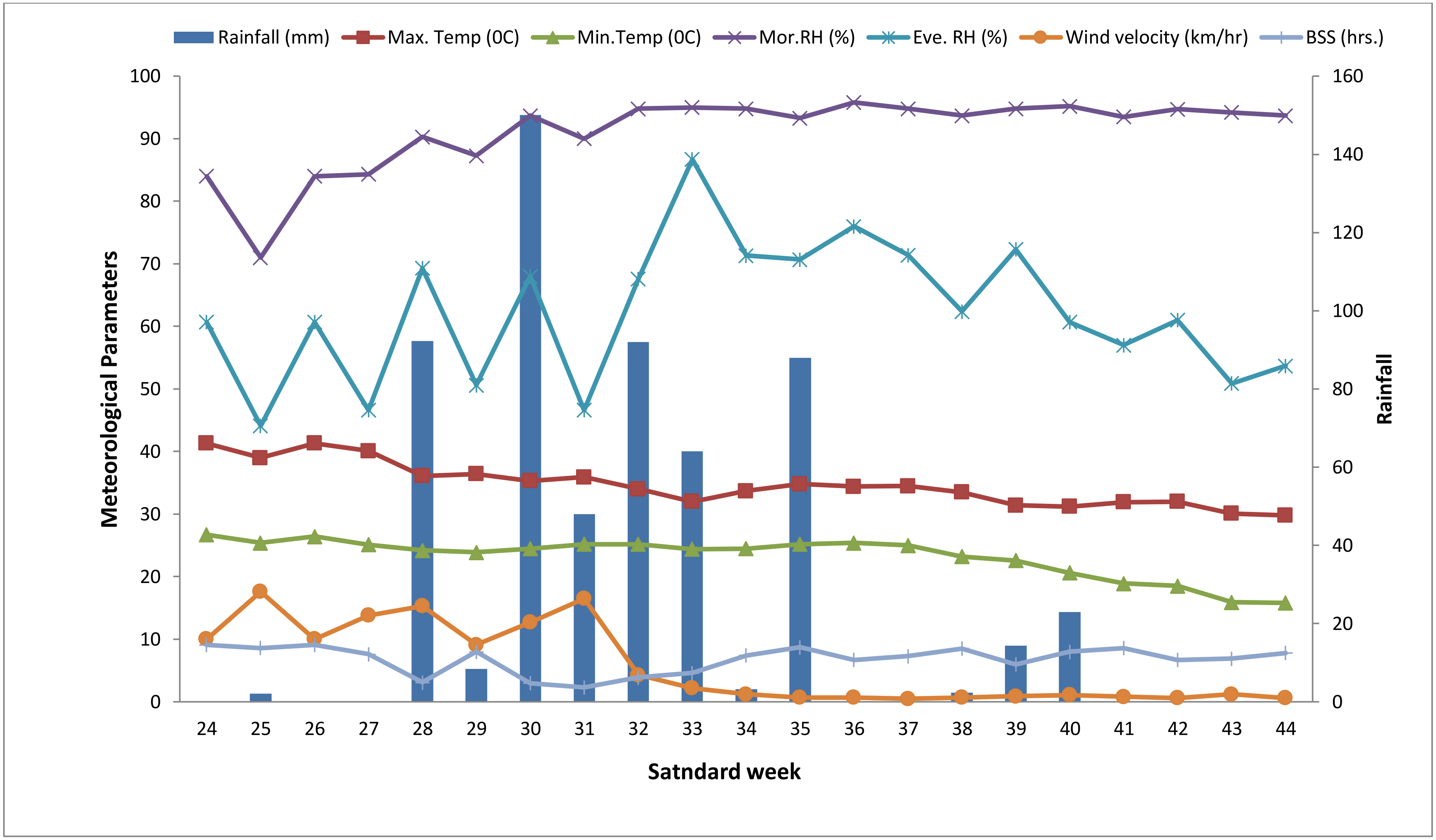


Fig. 3.1a: Mean weekly meteorological data during the crop growing season (*Kharif* 2019)

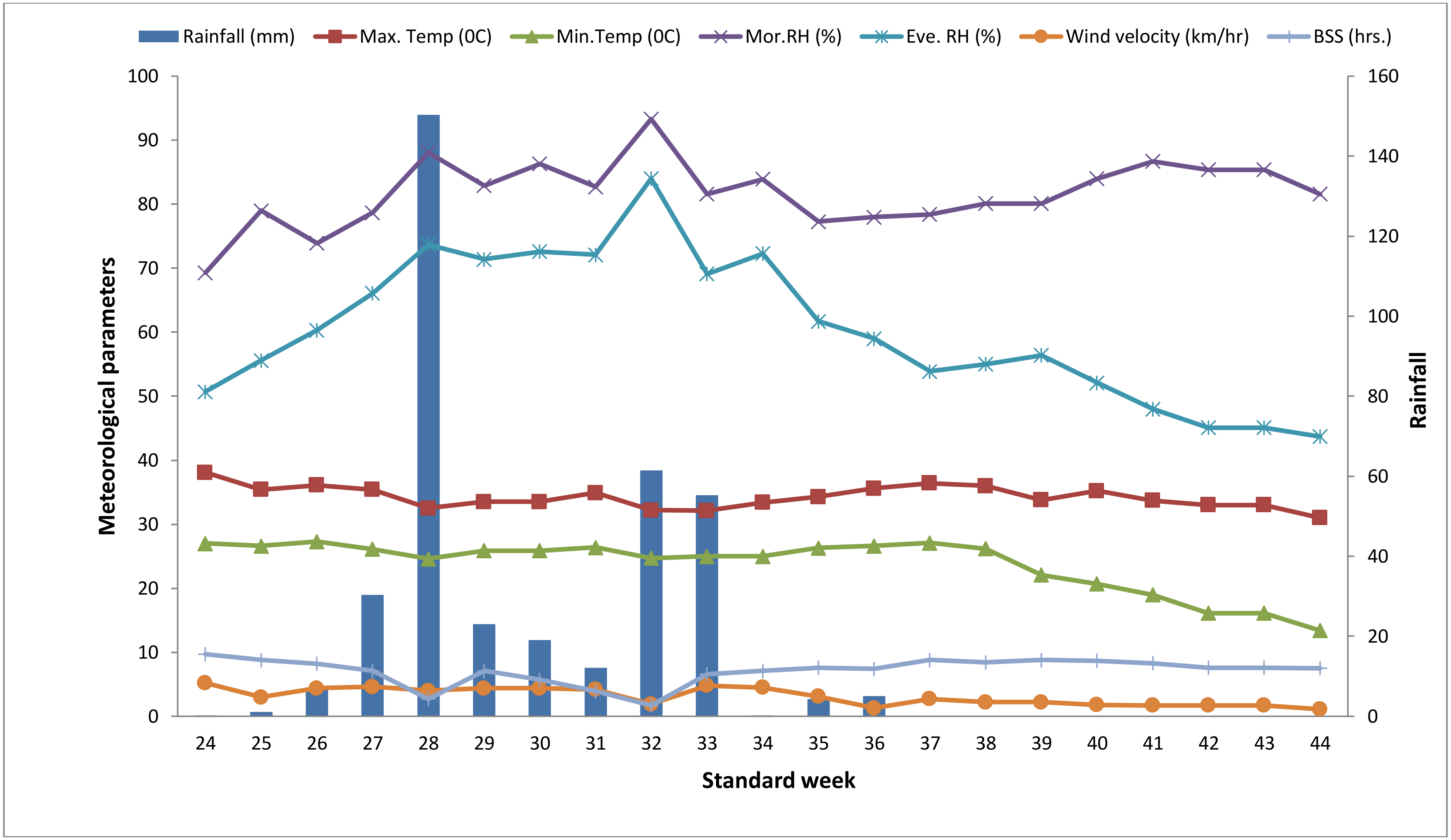


Fig. 3.1b: Mean weekly meteorological data during the crop growing season (*Kharif* 2020)

monsoon sets in the third or fourth week of June, reaches its peaks in July and August, and continues up to September, cyclonic weather leads to few winter rains. The area receives mean annual rainfall of 845 mm, of which 80-90 per cent is received from June to September. Winter season extends from November to February, whereas frost occurs generally in the end of December and may continue up to the end of January. The mean minimum temperature reaches as low as 3°C in winters, while during summer the mean maximum temperature varies from 43-45°C in the month of May.

The meteorological data depicted graphically in Figure 3.1a & 3.1b and presented in Appendix I & II have showed that average maximum and minimum weekly temperature varied from 40.3 and 38.5^{0}C to 15.9 and 16.1^{0}C during the crop period in the year 2019 and 2020, respectively. However, the mean maximum and minimum relative humidity varied from 95.8 and 88.1 to 46.8 and 41.7% during the crop period in both the year, respectively. Though, the total rainfall 631.8 and 419.8 mm was received during first and second year of investigation.

The mean weekly weather data for the crop period of 2019 and 2020 was recorded from the meteorological observatory of the University are depicted in Fig. 3.1a and 3.1b and presented in Appendix I &II.

3.3 Characteristics of the Soil of Experimental Field

A composite soil sample to a depth of 0-15 cm was collected from experimental field prior to sowing of the crops and then analyzed for physico-chemical properties. The soil of the experimental field was sandy loam in texture and slightly alkaline in reaction. The soil was medium in available phosphorus and potassium but low in organic carbon and available nitrogen and the average values are presented in Table 3.1.

Table 3.1 Physico-chemical composition of the experimental soil.

Sr.	Particular	Values		Method used
		2020	2021	
A. Physical Properties				
1.	Soil texture	**Sandy loam**	**Sandy loam**	Bouyoucos hydrometer method (Bouyoucos, 1962)
1.1	Sand (%)	**47.9**	**47.7**	
1.2	Silt (%)	**16.8**	**16.2**	
1.3	Clay (%)	**35.3**	**36.1**	
2.	Bulk density (Mg/m^3)	**1.48**	**1.49**	Core sampler method (Blake,1965)
3.	Particle density (Mg/m^3)	**2.81**	**2.80**	
4.	Soil pH (1:2.5, soil: water suspension)	**7.89**	**7.88**	Glass electrode pH meter (Jackson, 1973)
5.	EC (dS/m) 1:2.5, Soil: water suspension	**0.22**	**0.23**	Solbridge conductivity meter method (Jackson, 1973)
B. Chemical Properties				
1.	Organic carbon (%)	**0.49**	**0.49**	Modified Walkley and Black method (Jackson, 1973)
2.	Available N (kg/ha)	**225.90**	**226.10**	Alkaline potassium permanganate method (Subbiah and Asija,1956)
3.	Available P_2O_5 (kg/ha)	**19.30**	**19.90**	Olsen's method (Olsen *et al.*, 1954)
4.	Available K_2O (kg/ha)	**200.80**	**202.50**	Flame photometer method (Jackson, 1973)

Table 3.2 Cropping History of the Experimental Field

The crops grown in different seasons in the last five years are given in table 3.2

Table 3.2 Cropping History of the Experimental Field

Year-wise	Season

	Kharif	***Rabi***
2016-17	Rice	Wheat
2017-18	Rice	Mustard
2018-19	Rice	Wheat
2019-20	Rice (experiment)	Wheat
2020-21	Rice (experiment)	Wheat

This study was done to know the previous crops grown in the experimental piece of land and may be helpful in the interpretation and discussion of the results.

3.5 Layout Plan

The experiment entitled "Effect of crop establishment methods and weed management options on weed dynamics and performance of basmati rice (*Oryza sativa* L.)"was laid out in split plot design with three main factors and five sub factors, the details of the experiment is given below:

1. Design : Split Plot Design
2. Replication : 04
3. Gross plot size : 6.0 m × 3.6 m = 21.6 m^2
4. Net plot size : 5.0 m × 2.8 m = 14 m^2
5. Irrigation channel : 1.5 m wide

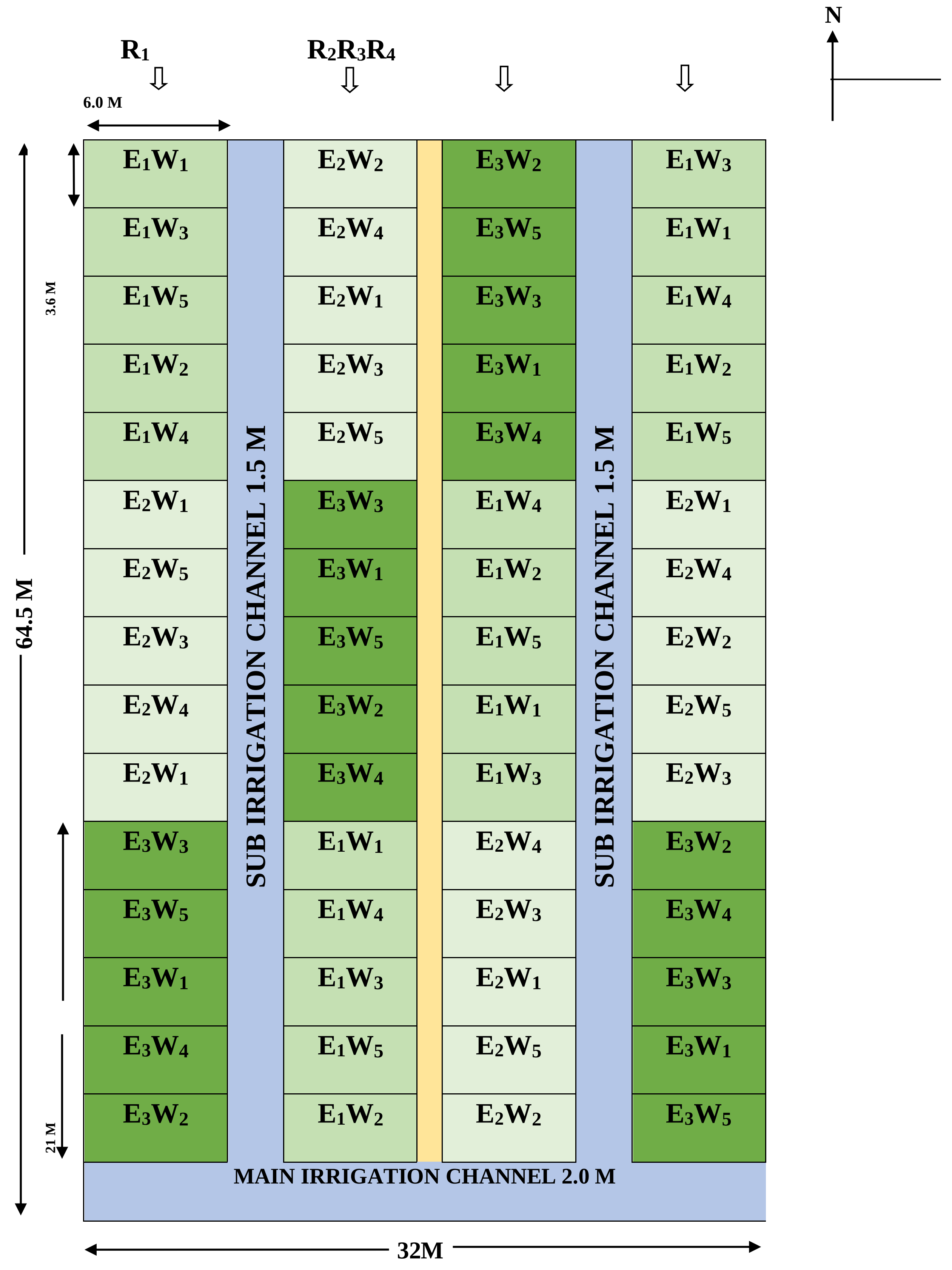


Fig. 3.2 Layout Plan of the Experiment

6. Crop	:	Basmati Rice
7. Variety	:	Pusa Basmati- 1509
8. Season	:	*Kharif*, 2019 and 2020
9. Seed rate	:	30 kg/ha
10. Spacing at flats	:	20 cm x10 cm
11. Spacing at beds	:	15 cm x 10 cm

3.3 Treatment and their details:

A- Main Plot Treatment (Crop Establishment Methods)	
E_1	Conventional Puddled Transplanting (CPT)
E_2	Unpuddled Flat (UPF)
E_3	Furrow Irrigated Raised Beds (FIRB)
B- Sub Plot Treatment (Weed Management)	
W_1	Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT
W_2	Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT
W_3	Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT
W_4	Two hand weedings
W_5	Weedy check

3.6 Preparation of Establishment Methods:

3.6.1. E_1: Conventional Puddled Transplanted Rice (CPT)

Conventional puddling involving 2 dry-harrowing, 2 passes of cultivator followed by 2 wet-tillage operations and one field leveling with a wooden plank was done, after that water was impounded, followed by manual transplanting of seedlings at 20- by 20-cm spacing.

3.6.2. E_2: Unpuddled Flat(UPF)

Unpuddled Flat involving2 dry-harrowingfollowed bycultivator was performed without puddling, after that water was impounded, followed by manual transplanting of 21-days old seedlings at 20 x10 cm spacing. The plots were kept watering for initial two weeks, and in subsequent irrigations, applied at the appearance of light cracks at the soil surface, the field was flooded up to the point where 5 cm water was standing. In the soil used in present study, the hair-line cracks appear at field capacity moisture regime.

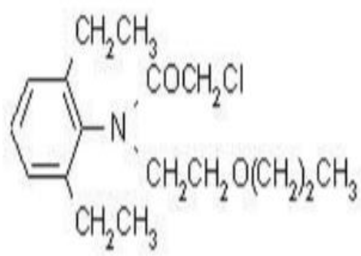
3.6.3. E_3:Furrow Irrigated Raised Beds (FIRBs)

At the beginning of the experiment after harvest of the wheat crop soil was tilled by three harrowing and three plowings followed by one field leveling with a wooden plank, and raised beds were made using a tractor-drawn multi crop raised bed planter with inclined plate seed metering devices. The dimensions of the wide beds were 90 cm wide (top of the bed) x 12 cm height x30 cm furrow width (at top). Transplanting of seedling per hill in six rows at 15-cm spacing on the wide raised beds. Plant-to-plant spacing was 10 cm to maintain the population equal to that of the conventional transplanted method. The plots would be kept flooded for 2 weeks after seeding and subsequent irrigations were applied to completely fill the furrows at the appearance of hair-line cracks at the soil surface at the bottom of the furrow.

3.7 General description of the herbicides used

3.7.1. Pretilachlor

- Group: Anilides
- Molecular formula: $C_{17}H_{26}CINO_2$
- Structural formula:



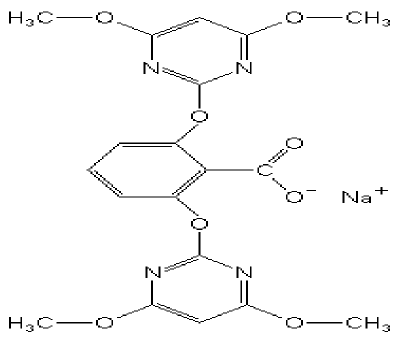
- Chemical Name: 2-Chloro-N- (2, 6-diethylphenyl)-N-(2-propoxyethyl) acetamide
- Trade name: Rifit/Craze/Eraze
- Formulation: Emulsifiable concentrate (50%)
- Manufacturer: Syngenta, Dhanuka and Nagarjuna
- **Mode of action:**

It is one of the commonly used soil surface applied herbicide. Pretilachlor affects the early development of susceptible plants by the inhibition of protein, nucleic acid, lipid and gibberellic acid synthesis.

3.7.2 Bispyribac sodium

- Trade name: Nominee Gold
- Active substance: Bispyribac sodium salt
- Chemical name: Sodium 2, 6 – [(4, 6-dimethoxypyrimidin-2- y1) oxy] benzoate
- Molecular formula: $C_{19}\ H_{17}\ N_4\ NaO_8$
- Use: - As post-emergence to control of a wide range of weed in rice field

- **Structural formula:**



Mode of action

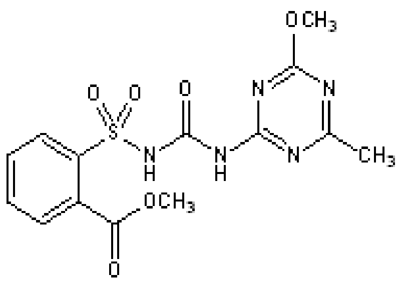
Bispyribac – sodium is classified as a group 2 herbicide. The primary mode of action is as inhibitor of acctolactate synthase (ALS) in the biosynthesis of branched-chain amino acid. Within a few days after application start chlorotic appearance and stop the growth of plant followed by necrosis and death of plant tissues. Selectivity is largely based on differential rates of metabolism among species.

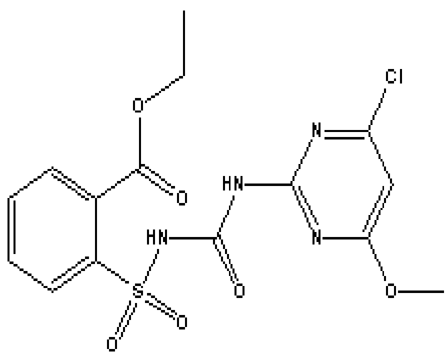
3.7.3 Almix

Group: metsulfuron methyl- Triazinyl sulfonylurea, chlorimuron ethyl-Pyrimidinyl sulfonylurea.

Molecular formula: metsulfuron methyl-$C_{14}H_{15}N_5O_6S$, chlorimuron ethyl-$C_{15}H_{15}ClN_4O_6S$.

Structural formula:





metsulfuron methyl chlorimuron ethyl

- **Chemical Name:** 2-{[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) amino] oxomethyl] sulfamoyl} benzoic acid methyl ester and ethyl 2-(4-chloro-6-methoxypyrimidin-2-yl) amino] carbonyl] amino] sulfonyl] benzoate.
- **Trade name:** DuPont Almix
- **Formulation:**metsulfuron methyl 10% + chlorimuron ethyl 10% WP
  - **Manufacturer:** DuPont, Curin (Dhanuka Agritech Ltd.), Atlantis (Bayer)
  - **Mode of action:**

Branched chain amino acid synthesis (ASL or AHAS) inhibitor. Acts by inhibiting biosynthesis of the essential amino acids' valine and isoleucine, hence stopping cell division and plant growth in shoot and roots.

3.8 Description of Variety

Pusa Basmati 1509 is the first early maturing Basmati rice variety with seed to seed maturity of only 120 days and average yield of 4.25 to 6.5 tonne hectare^{-1}. Pusa Basmati 1509 is a semi-dwarf (95-100 cm). Basmati rice variety with sturdy stem and plant height ranging from 95 - 100 cm. It takes115-120 days for seed to seed maturity, the shortest duration for any Basmati rice variety released so far. Pusa Basmati 1509 can help saving up to 5-6 irrigations (about 33% saving of irrigation water).

3.9 Cultural operations

The detail of cultural operations carried out during pre and post-transplanting of rice crop in experimental field are presented in Table 3.4.

Table 3.4: Schedule of cultural operations carried out in the experimental field.

Sr.	Particulars	Date of operation		Method Used
		2019-20	2020-21	

1.	Nursery sowing	28.06.2019	20.06.2020	Manually
2.	Layout	17.07.2019	10.07.2020	Manually
3.	Field Preparation	As per treatment	As per treatment	Tractor drawn harrow
4.	Basalfertilizer application	19.07.2019	11.07.2020	Manually
5.	Transplanting	20.07.2019	12.07.2020	Manually
6.	Pre emergence herbicides application	23.07.2019	15.07.2020	Manually(By knapsack sprayer)
7.	Post emergence herbicides application	09.08.2019	01.08.2020	Manually (By knapsack sprayer)
8.	First Hand weeding	14.08.2019	07.08.2020	Manually
9.	First top dressing of N	15.08.2019	03.08.2020	Manually
10.	Second hand weeding	30.08.2019	22.08.2020	Manually
11.	Second top dressing of N	02.09.2019	26.08.2020	Manually
12.	Insecticides application	30.09.2019	14.09.2020	Manually
13.	Harvesting	28.10.2019	19.10.2020	Manually by sickle
14.	Threshing	31.10.2019	23.10.2020	Manually

3.9.1 Nursery raising

The seedling of rice variety Pusa Basmati - 1509 (30 kg ha^{-1}) was raised in nursery by "Wet bed method". Three seed bed of 8 x 1.25 m size was prepared in dry condition. On sowing date, the beds were flooded with water and puddle manually. After leveling, a mixture of 135 g urea (60 kg ha^{-1}) and 187.5 g single super phosphate (30 kg ha^{-1}) per bed was broadcasted and incorporated in to the soil. Sprouted seeds were sown and beds were kept saturated initially up to a week and then submerged with a thin layer of water throughout the nursery period. These beds were irrigated on alternate days during rainless period.

3.9.2 Application of fertilizers

The required quantities (90:40:40) of N, P, K and Zn (25 Kg $ZnSO_4$) were applied in the different treatments by Urea, Diammonium Phosphate, Muriate of potash, Zinc sulphate, respectively. Half dose of nitrogen and full dose of other nutrients was applied as basal and rest nitrogen was applied in two equal splits at tillering and panicle initiation stages into the soil uniformly.

3.9.3 Uprooting of seedlings, transplanting and gap filling

The nursery beds were irrigated one day before seedling uprooting to make the soil soft and 25 days old seedlings were uprooted by holding at the base and pulling them up one by one and their roots were washed in running water to remove the soil. Transplanting was done manually keeping two seedlings hill^{-1} at the spacing of 20x10 cm in flats and 15 x 10 cm on the beds. One week after transplanting, gap filling was done from the same nursery to maintain the optimum plant population.

3.9.4 Water management

A thin layer of water (approximately 3.0 cm) was maintained during the initial stage of crop growth for better establishment of seedlings and maximum 5.0 cm at tillering stage and later an intermittent irrigation at the time of panicle initiation, flowering and grain formation stage were applied. Water was drained out from the field one week before the harvesting of crop.

3.9.5 Plant protection measures

In order to control stem borer, leaf hopper, gundhi bug and other insects, the recommended insecticide as Cartap hydro chloride 4G was applied @ 20 kg ha^{-1}.

3.9.6 Harvesting and threshing

Harvesting was done manually when the crop reached at full physiological maturity stage. First of all, the border rows were harvested and separated. Later, the crop from net plot area was harvested and sun dried. The harvested material from each plot was carefully bundled, tagged and brought to threshing floor. Threshing was done plot wise and grains were cleaned, dried and weighed separately for each net plot and computed to q ha^{-1} at 14% moisture level. The straw yield was obtained by subtraction grain yield from biological yield, also recorded plot wise after sun drying and computed to q ha^{-1}.

3.10. Observation Recorded and Sampling Procedures

The various observations recorded during the course of investigation to study the effectiveness of different treatments are described in this section.

3.10.1. Observations on weed

Weed flora was identified for the prevalence in relation to each other species that were exists in the experimental plots and are listed in the chapter 4.

3.10.1.1 Weed density (m^{-2})

The number of individual weed present in the field was recorded at 30, 60 and 90 DAT. Grasses, BLW and other weeds present within three randomly selected 0.5 m x 0.5 m quadrate in each net plot area were counted separately, converted it to number of weeds m^{-2} before subjecting to statistical analysis.

3.10.1.2. Dry matter accumulation by weeds (g m^{-2})

Weed samples from two randomly selected spots for each plot were taken at 30, 60 and 90 DAT with the help of quadrate measuring 0.5 m x 0.5 m. The weeds were collected as grassy, BL and other weeds in sample. The samples were oven dried at 70^0Ctill constant weight achieved. Dried weed samples weighed and the weight thus taken was expressed in terms of m^{-2} before subjecting to statistical analysis.

3.10.1.3. Weed control efficiency (%)

The weed control efficiency (WCE) was calculated by the following formula and expressed in percentage:

$$\text{WCE (\%)} = \frac{\text{DWC}-\text{DWT}}{\text{DWC}} \times 100$$

Where,

WCE = Weed control efficiency (%)

DWC = Dry weight of weeds in weedy check plot (g m^{-2})

DWT = Dry weight of weeds in treated plot (g m^{-2})

3.11. Observations on crop

3.11.1. Growth Studies

3.11.1.1 Plant height (cm)

The plant height was measured from the base of plant to tip of the fully opened leaf at 30, 60, 90 DAT and at harvest (after panicle emergence) the height was measured from the base of the plant to the tip of the upper most spikelet and expressed as average plant height in cm.

3.11.1.2 Number of tillers (m^{-2})

Number of tillers was recorded from net plot area of 1 m^2 at 30, 60, 90 DAT and at harvest stage.

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

Dry matter accumulation was recorded by selecting five hills randomly from observation row of each plot. Selected hills from sampling area were cut carefully closed to the ground surface at 30, 60, 90 DAT and at harvest stage. After sun drying these samples were collected in paper bags by cutting in small pieces and put in a electric oven at 65±1 ^{0}C till constant weight. After this the weight was recorded on electronic balance and expressed as dry matter accumulation in gm^{-2}.

3.11.1.4 Crop Growth Rate (gm^{-2}/day)

It was worked out through the standard procedures described by Hunt (1978) as follows**:**

$$\text{CGR} = \frac{\text{W2} - \text{W1}}{\text{T2} - \text{T1}}$$

Where,

W_1 and W_2 are dry weight (g/hill)at time T_1 and T_2, respectively.

3.11.1.5 Leaf area index (LAI)

Leaf area index was calculated for rice crop at successive growth stages. The total leaf area was determined by length × maximum width method, the product being multiplied by a correction factor of 0.75 given by Yoshida (1981) for rice. The leaf area data were utilized for determining LAI by the formula as described by Watson (1952).

Leaf area index was obtained by selecting plants of 100 cm row length and then dividing total leaf area of plants by 2000 cm^2 ground area.

$$\mathcal{LAI} = \frac{Leafarea(cm^2)}{Landarea(cm^2)}$$

3.11.2 Yield and Yield Attributes

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

Shoots bearing panicles at the time of harvesting were recorded by using a quadrate of one square meter in each plot as per procedure followed for counting number of tillers at each successive stage, considered as number of panicles m^{-2}.

3.11.2.2 Length of panicle (cm)

All panicles were selected from three tagged plants from each plot and grouped into small, medium and large size. From these groups 5 panicles were selected and length was measured and average of all selected panicles were reported as length of panicle.

3.11.2.3 Number of filled grains per panicle

The panicles selected for measuring length were used to record the number of grains/panicle. The grains were removed by threshing and number of filled and unfilled grains were counted and average number of grains per panicles was worked out.

3.11.2.4 Test weight (g)

A handful of seeds were taken without any bias from the total seeds of the net plot, after threshing and cleaning. One thousand filled grains from each plot samples were counted and weighed on electronic balance and their weight was expressed in grams.

3.11.2.5 Biological yield (q ha^{-1})

The total above ground produce (grain + straw) was recorded on dry weight basis after sun drying from net plots and expressed in (q ha^{-1}).

3.11.2.6 Grain yield (q ha^{-1})

After cleaning and drying the grains, the grain yield was recorded in kg per plot. The moisture percentage in 100 g samples drawn from each treatment was determined with the help of moisture meter and grain yield per plot was adjusted to 14 per cent moisture. The yield of net plot, thus converted to q ha^{-1}.

3.11.2.7 Straw yield (q ha^{-1})

Straw yield was obtained by subtraction of grain yield from biological yield plot wise and expressed in q ha^{-1}.

3.11.2.8 Harvest index (%)

The harvest index was worked out as:

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield (kg/ ha)}}{\text{Biological yield (kg/ha)}} \text{ x } 100$$

3.12 Chemical analysis of plant samples

3.12.1 Preparation of plant sample

The five plants sampled for estimating the dry matter production and nutrient uptake from each field at 30, 60 and 90 DAT and at harvest were thoroughly washed with distilled water and dried in hot air oven at 65^0C. Dried samples were powdered in a Willey mill to considerable fineness before storing them in polythene bags for further analysis.

3.12.2 Digestion of plant samples

Powdered whole plant samples were separately treated with concentrated HNO_3 for twelve hours for pre digestion. Then the predigested samples were treated with di-acid (HNO_3: $HCIO_4$) mixture (10:4 ratio) and digested on sand bath at low temperature till colorless white precipitate was obtained. The residue was dissolved in 6*N* HCI, filtered than the content was made to know volume by using 6*N* HCI. This was used for further nutrient analysis. The following analysis was carried out from the di-acid digested samples of whole plant.

3.12.2.1 Nitrogen

Nitrogen content in rice grain and straw was analyzed by micro-Kjeldahl method (Jackson, 1973).

3.12.2.2 Phosphorus

Phosphorus in digested samples was determined by Vanadomolybdophosphoric yellow color method (Jackson, 1973) by using spectrophotometer at 420 mm wavelength.

3.12.2.3 Potassium

Potassium in the aliquot was estimated with the help of flame photometer after appropriate dilution (Jackson, 1973).

3.12.3 Nutrient uptake by crop (kg ha^{-1})

The nutrient uptake by grain and straw was obtained by multiplying resultant nutrient content with the corresponding yield and moisture factor (MCF) and then divided by 100.

The value of MCF was taken as 0.86 for grain and 0.82 for straw. The formula in use was:

$$\text{Nutrient Uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (\%)} \times \text{grain or straw Yield (Kg ha}^{-1}) \times \text{MCF}}{100}$$

3.12.4 Nutrient content and uptake by weeds (kg ha^{-1})

The nutrient uptake in weeds was calculated with the help of a representative sample from the dried weed sample which was further ground and then passed through a 2 mm sieve. It was determined by multiplying by resultant nutrient content with the dry weight of weeds. The formula used for the computation of nutrient uptake by weeds was:

$$\text{Nutrient uptake by weeds (kg ha}^{-1}) = \frac{\text{Nutrient content (\%) x total weed dry weight (kg ha}^{-1})}{100}$$

3.13 Soil Studies

3.13.1 Collection of soil sample

Soil sample was collected randomly from six places of the experimental field before transplanting of the Rice crop. The collected soil sample was mixed, grind and divided into the four equal parts, two parts of the sample discarded and remaining parts are farther mixed and this process is continuing repeat till the sample remaining not more than five hundred grams.

3.13.2 Preparation and storing of soil samples

Collected soil samples were dried in shade. The air-dried samples were ground with a wooden pestle and mortar and passed through 2 mm sieve to separate the coarse fragments (>2mm). The fine earth samples were stored in separate containers and used for various analyses.

3.13.3 Physico-chemical properties of soil

3.13.3.1Electrical conductivity

Electrical conductivity was determined in 1:2.5 soil-water extract using conductivity bridge and expressed as dSm^{-1} (Jackson, 1973).

3.13.3.2Soil pH

Soil pH was determined in 1:2 soil-water suspensions and 1:2.5 soil-*1N* KCI solutions by glass electrode pH meter method (Jackson, 1973).

3.13.3.3 Soil Bulk density

Soil samples were collected at initial and after harvest of crop at 0-5, 5-10 and 10-15 and 15-20 cm depth. An undisturbed soil cores were taken by hammering into the ground with the stainless-steel cutter edge cylinders 5 cm high and 6 cm in diameter from three places in each plot, mixed and bulked for analysis. Samples were oven-dried for 48 h at 105^0C; weighed. Bulk density of soil was calculated from the formula according to Blake and Hartge (1986).

$$\textbf{BD (Mg M}^3\textbf{) = (X-Y)//V}$$

Where,

X= Weight of core with oven dry soil,

Y= Weight of core,

V= Volume of core.

3.13.3.4Available nitrogen

Available nitrogen was estimated by alkaline $KMnO_4$ method where the organic matter in soil is oxidized with hot alkaline $KMnO_4$ solution. The ammonia evolved during oxidation is distilled and trapped in boric acid mixed indicator solution. The amount of NH_3 trapped is estimated by titrating with standard acid (Subbaiah and Asija, 1956).

3.13.3.5Available phosphorus

Available phosphorus was extracted with sodium bicarbonate (*0.5M*) at *pH* 8.5 (Olsen's reagent) and the amount of P in the extract was estimated by chlorostannous reduced phosphomolybdate blue colour method using spectrophotometer at wave length of 660 mm (Jackson, 1973).

3.13.3.6Available potassium

Available K was extracted with neutral normal ammonium acetate and determined by using flame photometer (Jackson, 1973).

3.13.3.7Organic carbon

The organic carbon content of a finely ground soil sample was determined by Walkely and Black's wet oxidation method as described by (Jackson, 1973) and expressed in g kg^{-1} soil.

3.14 Economic analysis

3.14.1 Cost of Cultivation (Rs ha^{-1})

Cost of cultivation of rice crop was calculated on the basis of local market price of different inputs used in cultivation and expressed as Rs ha^{-1}.

3.14.2 Gross Return (Rs ha^{-1})

The monetary value of grains and straw yield was computed in rupees at prevailing local market price of output. Gross return was obtained by adding monetary value of grain and straw and computed as Rs ha^{-1}.

3.14.3 Net Return (Rs ha^{-1})

Net return was calculated by deducting the cost of cultivation from respective gross return, treatment wise in Rs ha^{-1}.

3.14.4 Benefit: Cost ratio

The benefit: cost ratio was calculated by using following formula:

$$B\!:\!Cratio = \frac{Grossreturn\ (Rs/\ ha)}{Costofcultivation(Rs/\ ha)}$$

3.15 Statistical analyses

The data collected from the experiment was subjected to statistical analysis with following procedure of Split Plot Design as suggested by Cochran and Cox (1970). The standard error of mean was calculated and critical difference (C.D. at 5%) was worked out for comparing the treatment means, wherever “f” test was found significant.

Analysis of variance

Sources of variation	d.f.	SS	MSS	F-value calculated	F-value tabulated
Replication	3				
Establishment Methods (E)	2				
Error (a)	6				
Weed Management (W)	4				
ExW	8				
Error (b)	36				
Total	59				

Note: d.f. = Degree of freedom
SS= Sum of square
MSS= Mean sum of square

The standard error of mean and critical difference was calculated by the following formula:

(a) Establishment Methods

$$CDat\ 5\% = \sqrt{\frac{2EMS\ (a)}{r\times W}} \times \text{t 0.05 error (a) d.f.}$$

(b) Weed Management

$$CDat\ 5\% = \sqrt{\frac{2EMS\ (b)}{r\times E}} \times \text{t 0.05 error (b) d.f.}$$

(c) Comparing two Establishment Methodsat the same Weed Management option

$$CDat\ 5\% = \sqrt{\frac{2EMS\ (b)}{r}} \times \text{t 0.05 error (b) d.f.}$$

(d) For comparing two Establishment Methodsmean at the same or different Weed Management option $CD\ at\ 5\% = \frac{2\ (N-1)EMS\ (b) + EMS\ (a)}{r \times n} \times t\ 0.05\ error\ d.f.$

Coefficient of variation (CV):

It will be calculated by the following formula:

$$C.V.(\%) = \frac{\sqrt{\text{Variance of error}}}{\text{Mean}} x100$$

CHAPTER - 4 EXPERIMENTAL RESULT

In this chapter the results pertaining to various observations on crop growth studies, weed studies, yield attributes, yield, quality traits, nutrient contents and their uptake, with economic evaluation recorded during course of investigation entitled "**Effect of crop establishment methods and weed management options on weed**

dynamics and performance of Basmati rice (*Oryza sativa* L.).” during *kharif* season of 2019 and 2020. The Effect of crop establishment methods and weed management practices has been systematically tabulated for illustration with the help of table and diagrams for easy understanding of pattern. The relevant analyses of variance are given in Appendix from III to XXXI.

4.1 Weed studies

The crop infested *with Echinochloa colona, Echinochloa crusgalli, Eclipta alba, Eleusine indica, Phyllanthus niruri, Cyprus iria, Cyprus rotundus,Dactylocteninum aegyptium, Commelina benghalensis* etc. The most dominant weed species found in the field were *Echinochloa crusgalli, Cyprus rotundus, Eclipta alba, Eleusine indica,Phyllanthus niruri, Cyprus iria* etc**.**

Table 4.1: Weed flora prevalent in experimental field of rice

Sr.	Scientific name	Common name	Family
Grassy weeds			
1.	*Echinochloa colonum* (L.)	Swank, jungle rice	Poaceae
2.	*Echinochloa crusgalli* (L.)	Barnyard grass	Poaceae
3.	*Dactylocteninum aegyptium* (L.)	Crowfoot grass	Poaceae
4.	*Eleusine indica* (L.)	Goos grass	Poaceae
5.	*Cynodon dactylon* (L.)	Bermuda grass	Poaceae
6.	*Ischaemum rugosum*	Wrinkle grass	Poaceae
Broad leave weed			
1.	*Eclipta alba* (L.)	False daisy	Asteraceae
2.	*Caesulia axillaris*	Pink node flower	Asteraceae
3.	*Commelina benghalensis* (L.)	Day flower	Commelinaceae
4.	*Phyllanthus niruri* (L.)	Hajardana	Phyllanthaceae
Sedges			
1.	*Cyperus rotundus* (L.)	Purple nut sedges	Cyperaceae
2.	*Cyperus iria (*L.)	Yellow nut sedges	Cyperaceae

4.1.1 Total weed density (No. m^{-2})

The data regarding the effect of different treatments on density of total weeds are presented in Table 4.2, depicted in Fig 4.1, and their analysis of variance is given in appendix III. Total weed density (No. m^{-2}) at different days interval as influenced by various treatments. The total weed density increased at 60 DAT and thereafter decline with the advancement in crop growth. The effect of different crop establishment methods at different observation dates was significant. The minimum total weed density was recorded under conventionalpuddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum total weed density was recorded with unpuddled flatmethod (E_2) during both the years. At harvest the percent reduction in total weed density under conventionalpuddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 9.81 and 9.60, 17.44 and 14.55 during 2019 and 2020, respectively.

The weed management practices had significant effect on total weed density at different days interval of crop growth during both the years. The total weed density increased initially and reached maximum at 60 DAT under various weed management practices and there after declined at harvest. The effect of different weed management practices on total weed density was significant and two hand weedings was found most effective in reducing total weed density as compared to rest of the weed management practices. Among the herbicides, application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing the total weed density at every observation dates. At harvest, two hand weeding (W_4) and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) resulted into

Table 4.2: Effect of establishment methods and weed managementon density oftotal weed density(No.m^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Density of total weed (No.m^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E$_1$-Conventional Puddled Transplanting (CPT)	6.14 (50)	6.74 (57)	9.23 (96)	9.84 (108)	8.67 (87)	9.19 (97)	7.81 (71)	8.28 (77)
E$_2$-Unpuddled Flat (UPF)	8.80 (89)	9.22 (96)	11.36 (140)	11.85 (152)	10.45 (120)	10.74 (127)	9.46 (99)	9.69 (103)
E$_3$-Furrow Irrigated Raised Beds (FIRBs)	8.25 (81)	8.74 (89)	10.45 (122)	10.79 (128)	9.64 (106)	10.17 (115)	8.66 (86)	9.16 (93)
SE(m)±	***0.16***	***0.17***	***0.22***	***0.23***	***0.21***	***0.22***	***0.17***	***0.18***
C.D(P=0.05)	***0.56***	***0.59***	***0.77***	***0.80***	***0.73***	***0.76***	***0.59***	***0.62***
(W) Weed Management Options								
W$_1$-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	5.30 (29)	5.85 (35)	7.57 (58)	8.02 (65)	6.79 (46)	7.13 (51)	6.12 (37)	6.42 (41)
W$_2$-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	6.29 (41)	6.81 (47)	8.38 (71)	8.95 (81)	7.55 (57)	8.11 (66)	6.79 (47)	7.30 (54)
W$_3$-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	8.22 (68)	8.62 (75)	12.60 (159)	13.04 (170)	11.93 (142)	12.23 (150)	10.74 (116)	11.04 (122)
W$_4$-Two hand weedings	4.43 (20)	5.15 (27)	7.25 (53)	7.72 (60)	6.37 (41)	6.99 (49)	5.73 (33)	6.30 (40)
W$_5$-Weedy check	14.42 (209)	14.75 (219)	15.94 (256)	16.41 (271)	15.31 (235)	15.71 (248)	13.86 (192)	14.16 (201)
SE(m)±	***0.15***	***0.16***	***0.21***	***0.21***	***0.18***	***0.18***	***0.15***	***0.16***
C.D(P=0.05)	***0.46***	***0.48***	***0.63***	***0.63***	***0.54***	***0.55***	***0.47***	***0.48***

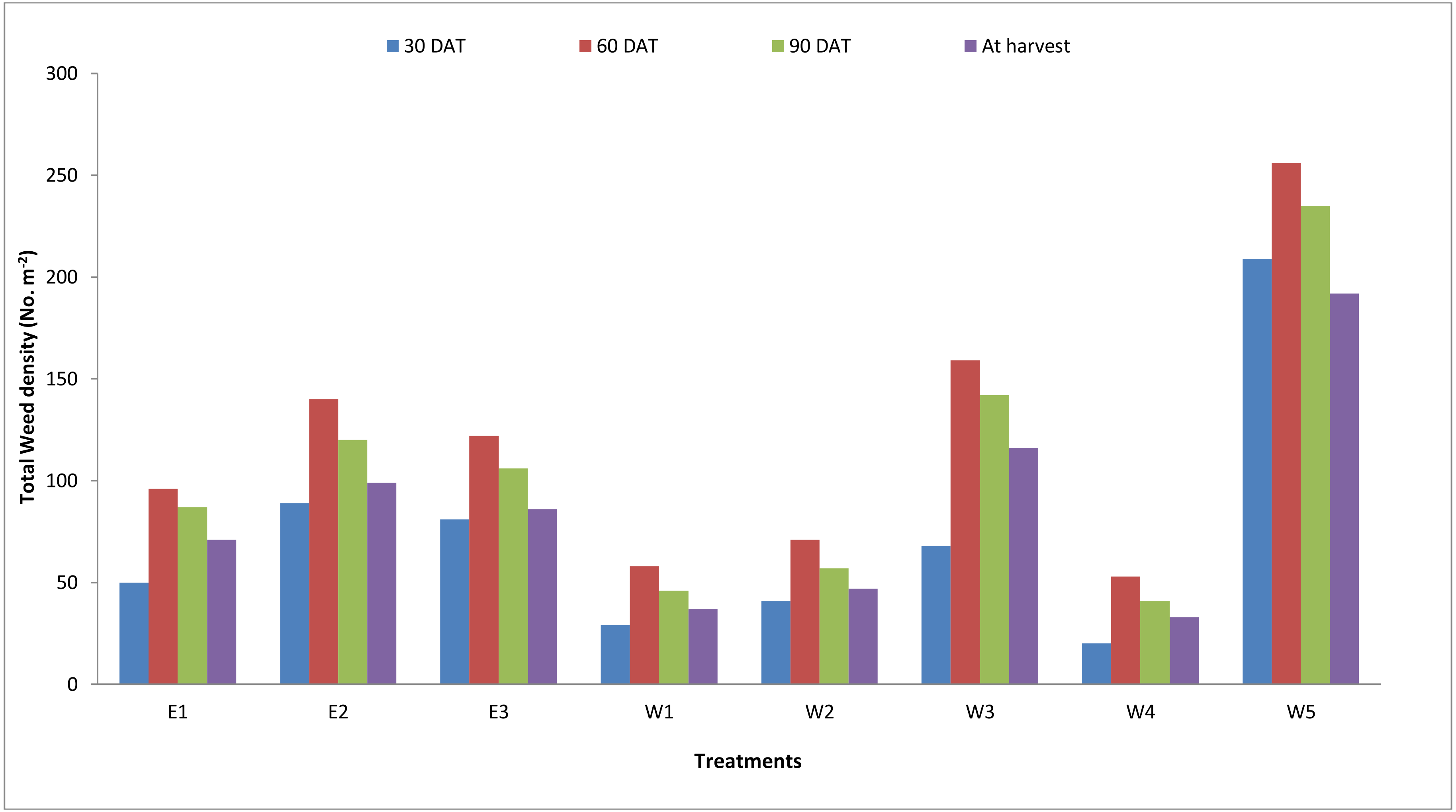


Fig.4.1(a): Effect of establishment methods and weed management on density of total weed (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

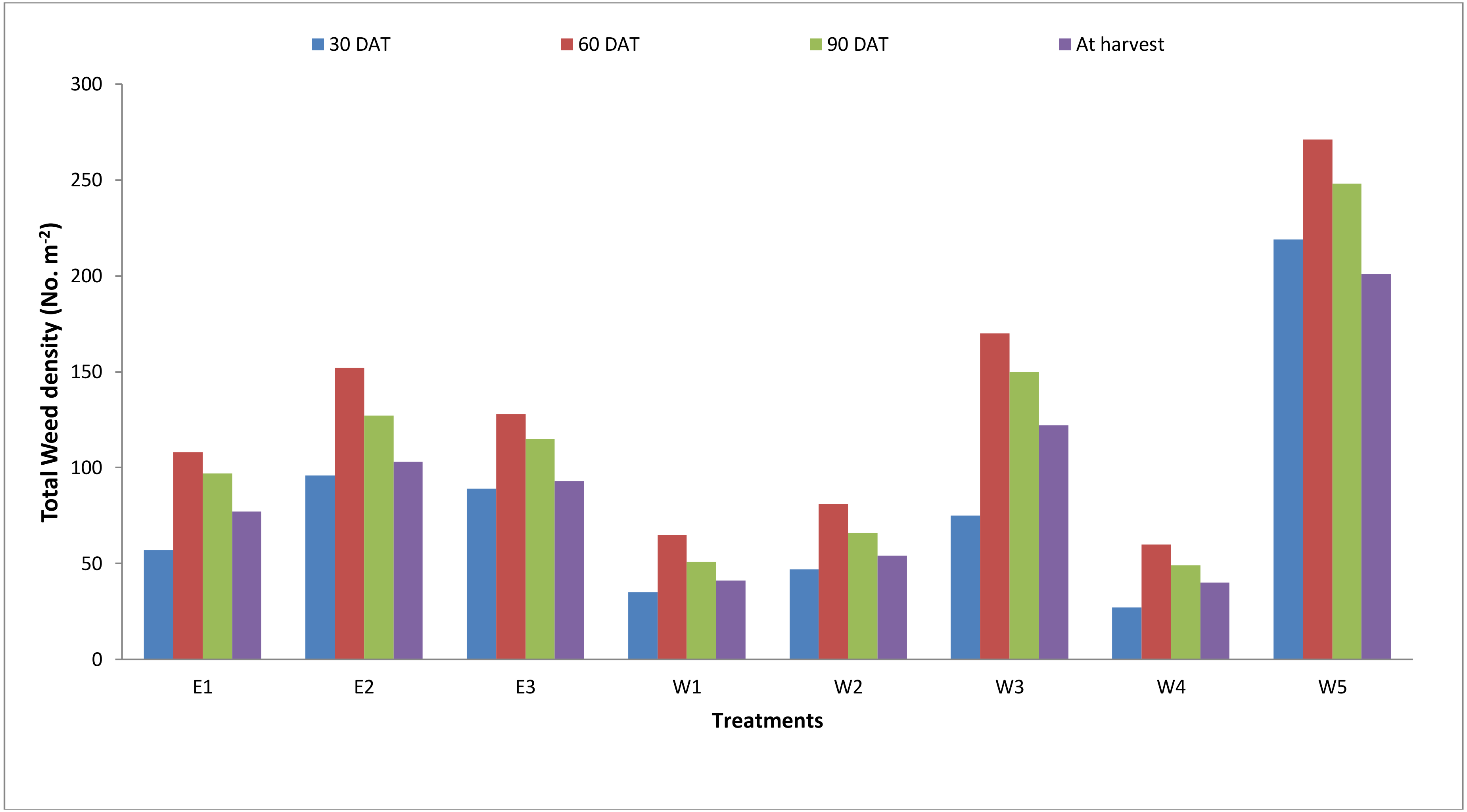


Fig.4.1 (b): Effect of establishment methods and weed management on density of total weed density (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

Table 4.3: Effect of establishment methods and weed managementon density of *Echinochloa crusgalli* (L) (No.m^{-2}) at 30, 60, 90 days

after transplanting and at harvest

Treatments	**Density of *Echinochloa crusgalli* (L) (No.m^{-2})**							
	30 DAT		**60 DAT**		**90 DAT**		**At harvest**	
	2019	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	2.59 (8)	2.80 (9)	3.64 (15)	3.81 (16)	3.20 (12)	3.64 (14)	2.92 (10)	3.31 (12)
E_2-Unpuddled Flat (UPF)	3.93 (17)	4.08 (18)	4.51 (21)	4.66 (23)	4.20 (19)	4.42 (21)	3.90 (16)	4.02 (17)
E_3-Furrow Irrigated Raised Beds (FIRBs)	3.20 (12)	3.48 (14)	3.78 (16)	4.01 (18)	3.37 (13)	3.74 (15)	3.07 (11)	3.40 (13)
SE(m)±	***0.09***	***0.06***	***0.08***	***0.09***	***0.07***	***0.08***	***0.06***	***0.06***
C.D(P=0.05)	***0.32***	***0.23***	***0.30***	***0.30***	***0.26***	***0.28***	***0.21***	***0.23***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.22 (5)	2.47 (6)	2.95 (8)	3.12 (9)	2.47 (6)	2.84 (8)	2.26 (5)	2.59 (6)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.69 (7)	2.87 (8)	3.36 (11)	3.56 (12)	2.95 (9)	3.36 (11)	2.69 (7)	3.05 (9)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	3.73 (14)	3.92 (15)	4.76 (22)	4.97 (24)	4.49 (20)	4.65 (21)	4.08 (16)	4.23 (17)
W_4-Two hand weedings	1.79 (3)	2.08 (4)	2.64 (7)	2.84 (8)	2.08 (4)	2.72 (7)	1.91 (3)	2.48 (6)
W_5-Weedy check	5.77 (33)	5.94 (35)	6.17 (38)	6.33 (40)	5.96 (35)	6.10 (37)	5.55 (31)	5.53 (30)
SE(m)±	***0.11***	***0.08***	***0.08***	***0.08***	***0.09***	***0.08***	***0.07***	***0.07***
C.D(P=0.05)	***0.33***	***0.24***	***0.24***	***0.25***	***0.26***	***0.25***	***0.22***	***0.22***

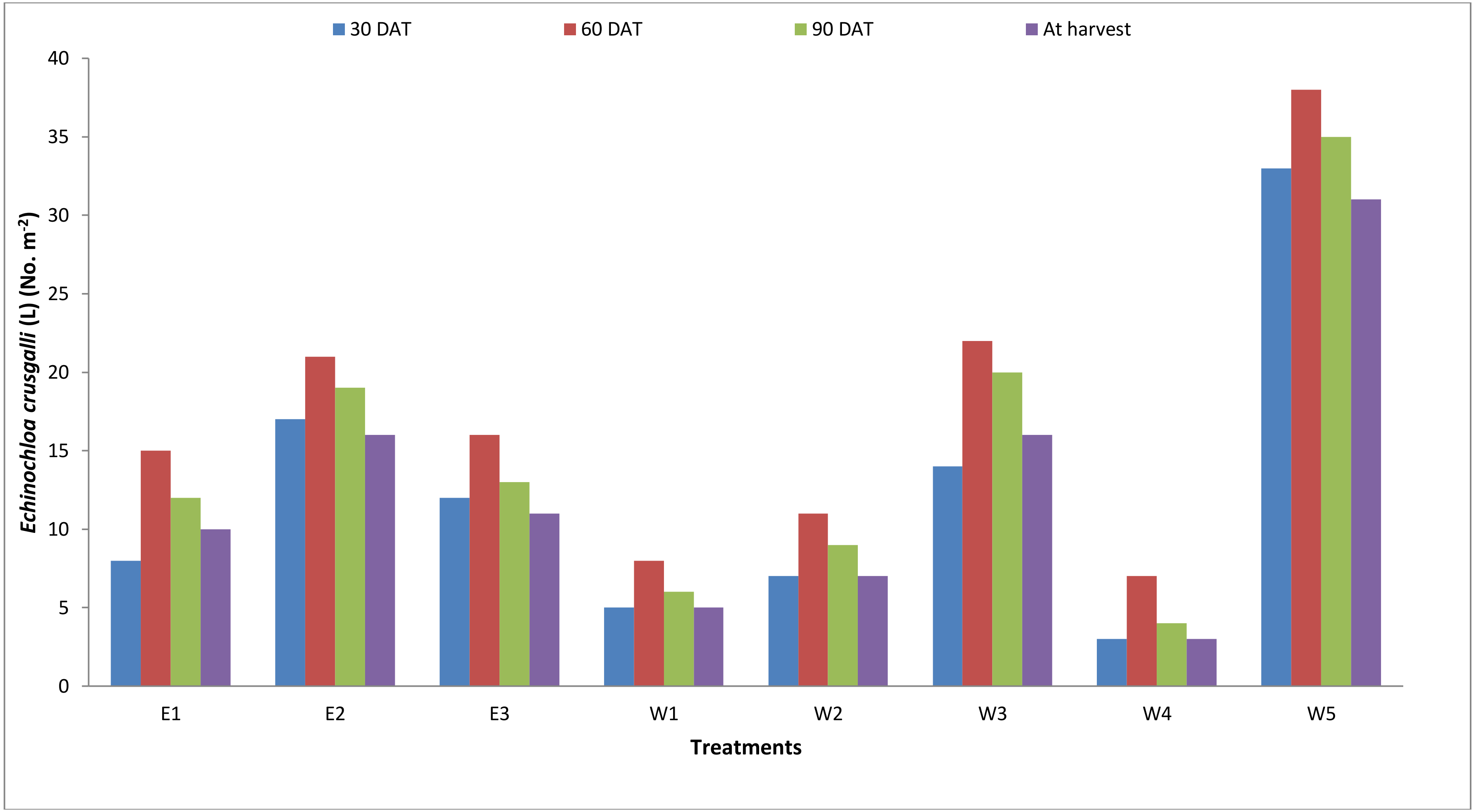


Fig.4.2 (a): Effect of establishment methods and weed management on density of *Echinochloa crusgalli* (L) (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

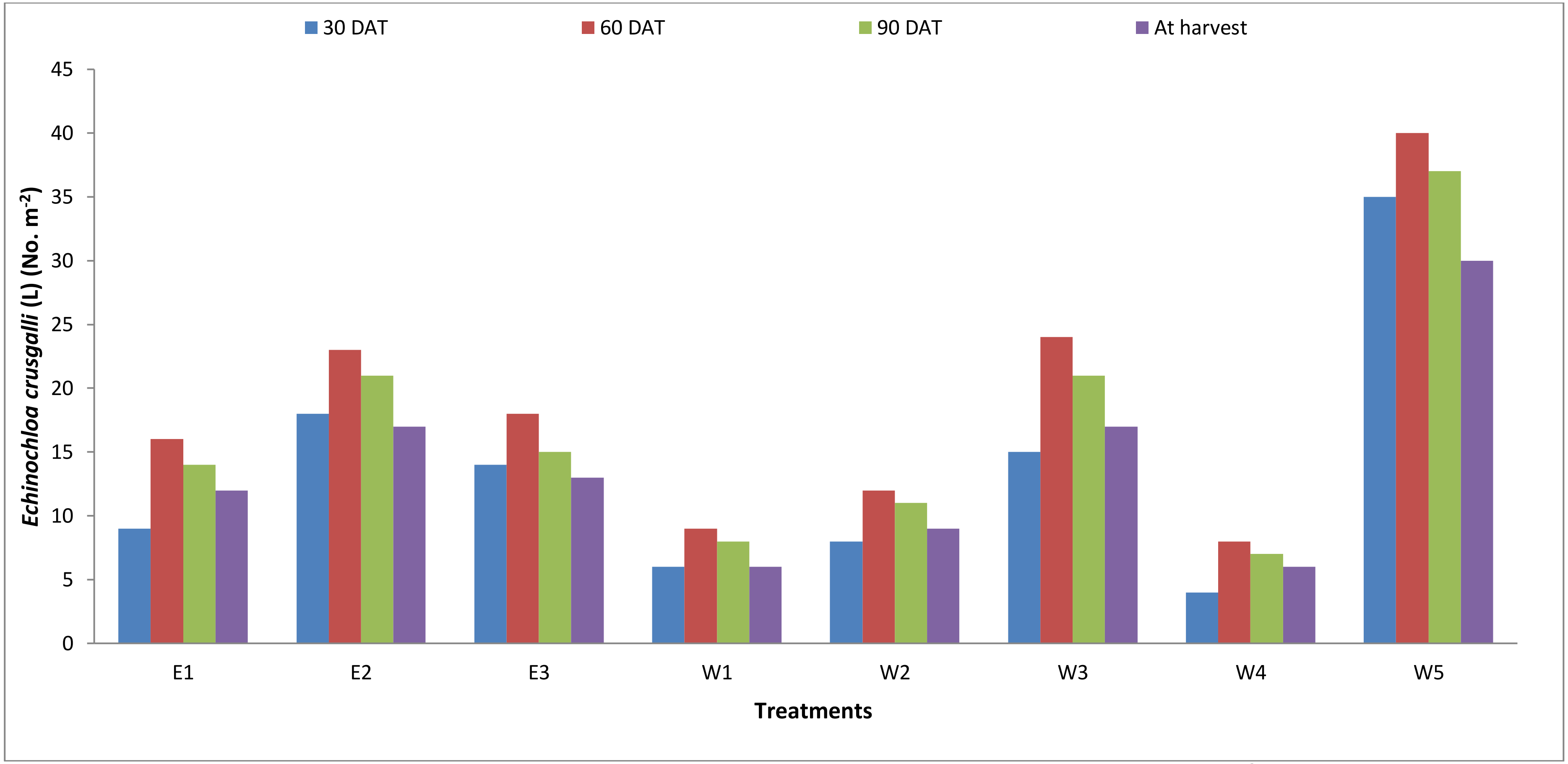


Fig.4.2 (b): Effect of establishment methods and weed management on density of *Echinochloa crusgalli* (L) (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

58.65, 55.50 and 55.84, 54.66 percent reduction into total weed density over weedy check during 2019 and 2020, respectively.

4.1.1.1 Density of *Echinochloa crusgalli*(L)(No.m^{-2})

The data regarding the effect of different treatments on density of *Echinochloa crusgalli*(L)are presented in Table no. 4.3, depicted in Fig 4.2, and their analysis of variance is given in appendix IV. Density of *Echinochloa crusgalli*(m^{-2})at different days interval as influenced by various treatments. The density of *Echinochloa crusgalli*(L)increased at 60 DAT and thereafter decline with the advancement in crop growth. The effect of different crop establishment methods at 30, 60, 90, and at harvest was significant. The minimum density of *Echinochloa crusgalli*was recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximumdensity of *Echinochloa crusgalli* was recorded with unpuddled flatmethod (E_2) during both the years. At harvest the percent reduction indensity of *Echinochloa crusgalli*under conventionalpuddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 4.88 and 2.64, 25.12 and 17.66 percent during 2019 and 2020, respectively.

The weed management practices had significant effect ondensity of *Echinochloa crusgalli*at different days interval of crop growth during both the years. Thedensity of *Echinochloa crusgalli*increased initially and reached maximum at 60 DAT under various weed management practices and the RE after declined at harvest. The effect of different weed management practices on weed density of*Echinochloa crusgalli*was significant and two hand weedings was found most effective in reducing density of *Echinochloa crusgalli*(L)as compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing thedensity of *Echinochloa*

Table 4.4: Effect of establishment methods and weed managementon density of *Cyprus rotundus*(L)(No.m^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Density of*Cyprus rotundus*(L)(No.m^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	2.87 (12)	3.07 (14)	4.73 (25)	5.02 (28)	4.68 (25)	4.81 (27)	4.25 (21)	4.36 (22)
E_2-Unpuddled Flat (UPF)	4.13 (21)	4.22 (21)	6.05 (40)	6.11 (40)	5.76 (36)	5.83 (37)	5.22 (29)	5.28 (30)
E_3-Furrow Irrigated Raised Beds (FIRBs)	3.62 (17)	3.72 (18)	4.98 (29)	5.10 (30)	4.76 (27)	5.19 (30)	4.32 (22)	4.72 (24)
SE(m)±	***0.08***	***0.08***	***0.11***	***0.11***	***0.09***	***0.10***	***0.10***	***0.10***
C.D(P=0.05)	***0.29***	***0.29***	***0.40***	***0.41***	***0.34***	***0.35***	***0.35***	***0.37***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.20 (5)	2.34 (5)	3.81 (14)	3.98 (16)	3.61 (13)	3.76 (14)	3.28 (11)	3.42 (11)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.55 (6)	2.67 (7)	3.91 (15)	4.1 (18)	3.70 (14)	3.97 (16)	3.37 (11)	3.62 (13)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	3.61 (13)	3.69 (14)	6.68 (44)	6.78 (46)	6.56 (43)	6.63 (44)	5.95 (35)	6.01 (36)
W_4-Two hand weedings	1.78 (3)	1.97 (4)	3.54 (12)	3.68 (13)	3.31 (11)	3.67 (13)	3.02 (9)	3.34 (11)
W_5-Weedy check	7.56 (57)	7.67 (59)	8.32 (70)	8.42 (71)	8.14 (66)	8.34 (69)	7.37 (54)	7.56 (57)
SE(m)±	***0.09***	***0.09***	***0.13***	***0.11***	***0.11***	***0.10***	***0.10***	***0.10***
C.D(P=0.05)	***0.29***	***0.27***	***0.39***	***0.33***	***0.34***	***0.31***	***0.32***	***0.29***

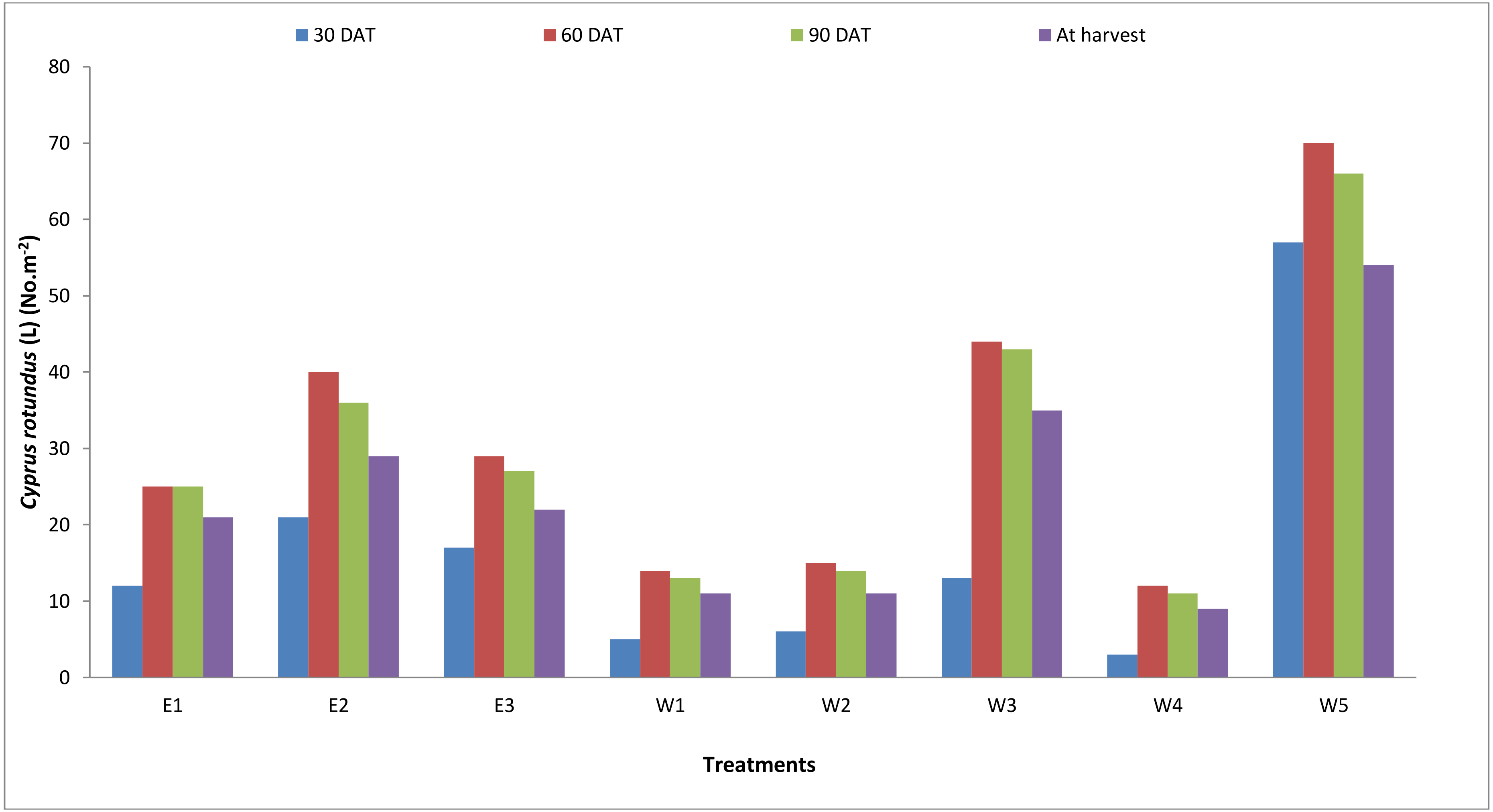


Fig.4.3 (a): Effect of establishment methods and weed management on density of *Cyprus rotundus* (L)(No. m^{-2}) at 30, 60, 90 DAT and at harvest(2019)

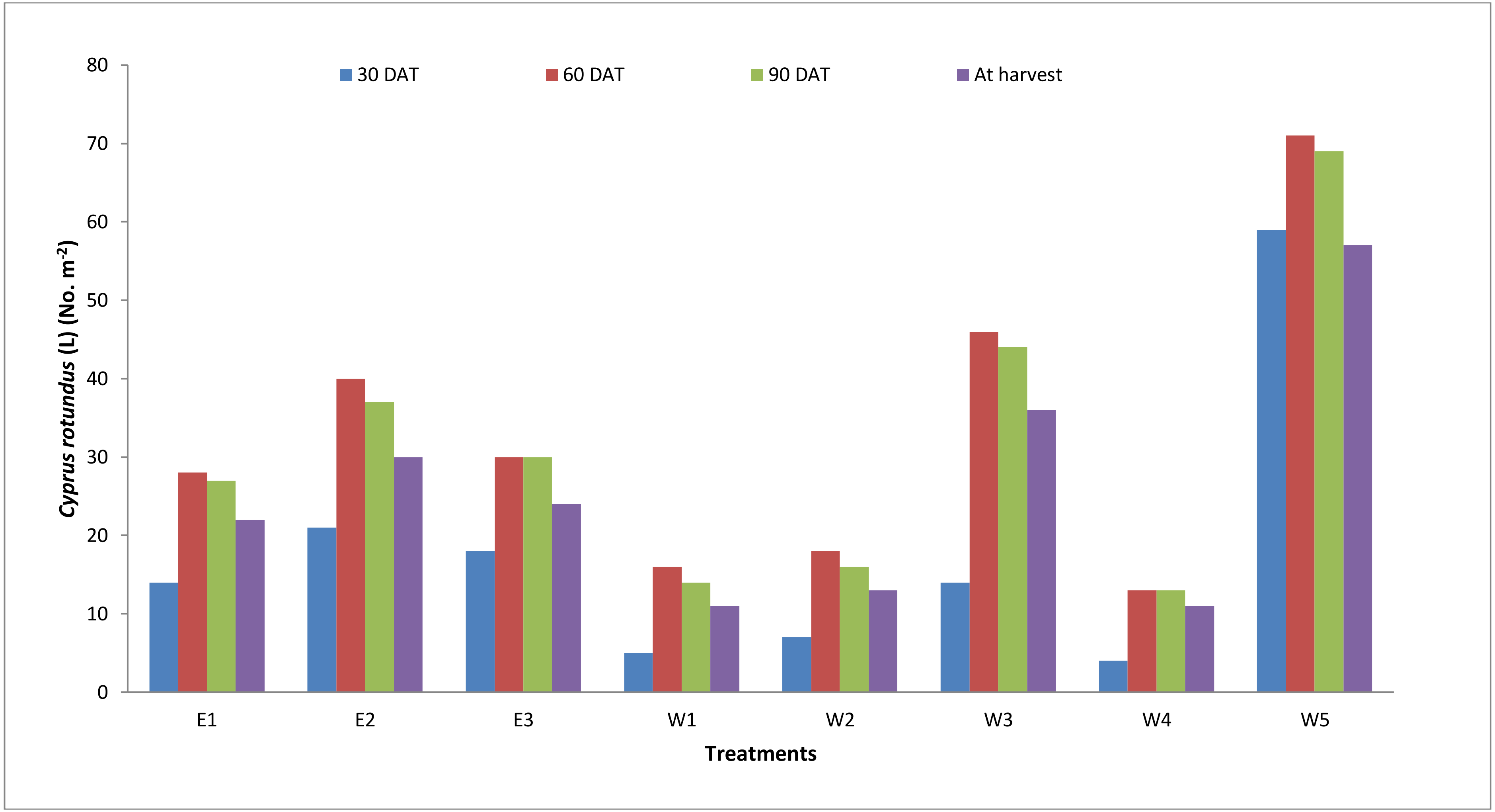


Fig.4.3 (b): Effect of establishment methods and weed management on density of *Cyprus rotundus* (L)(No. m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

crusgalli(L)at every observation dates. At harvest, two hand weeding (W_4) and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) resulted into 65.58, 55.15and 59.27, 53.16 percent reduction into density of *Echinochloa crusgalli*(L)over weedy check during 2019 and 2020, respectively.

4.1.1.2 Density of *Cyprus rotundus*(L) (No. m^{-2})

The data regarding the effect of different treatments on density of *Cyprus rotundus*are presented in Table 4.4, depicted in Fig. 4.3, and their analysis of variance is given in appendix V.Density of *Cyprus rotundus* (m^{-2})at different days interval as influenced by various treatments. TheDensity of *Cyprus rotundus* increased at 60 DAT and there after decline with the advancement in crop growth. The effect of different crop establishment methods at different observation dates was significant. The minimumDensity of *Cyprus rotundus* was recorded under conventionalpuddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum Density of *Cyprus rotundus*was recorded with unpuddled flat (E_2) method during both the years. At harvest the percent reduction inDensity of *Cyprus rotundus* under conventionalpuddled transplanting compared to furrow irrigated raised bed and unpuddled flatmethod was to 1.62, 7.62 and 18.58, 17.42 during 2019 and 2020, respectively.

The weed management practices had significant effect ondensity of*Cyprus rotundus* at different days interval of crop growth during both the years. Thedensity of *Cyprus rotundus* increased initially and reached maximum at 60 DAT under various weed management practices and there after declined at harvest. The effect of different weed management practices ondensity of *Cyprus rotundus*(L)was significant and two hand weedings was found most effective in reducingDensity of *Cyprus rotundus* as compared to rest of the weed management practices. In herbicides the application of

Table 4.5: Effect of establishment methods and weed managementon density of *Eclipta alba* (No.m^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Density of*Eclipta alba* (No.m^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E$_1$-Conventional Puddled Transplanting (CPT)	2.92 (9)	3.15 (11)	3.84 (15)	4.21 (18)	3.35 (12)	3.56 (14)	2.87 (9)	3.05 (10)
E$_2$-Unpuddled Flat (UPF)	3.23 (11)	3.39 (13)	4.36 (20)	4.63 (22)	3.69 (15)	3.88 (16)	3.16 (10)	3.31 (11)
E$_3$-Furrow Irrigated Raised Beds (FIRBs)	3.73 (15)	3.83 (16)	4.74 (23)	4.88 (25)	4.06 (17)	4.22 (19)	3.48 (13)	3.62 (14)
SE(m)±	***0.06***	***0.07***	***0.08***	***0.08***	***0.08***	***0.08***	***0.06***	***0.06***
C.D(P=0.05)	***0.23***	***0.26***	***0.28***	***0.30***	***0.27***	***0.28***	***0.22***	***0.23***
(W) Weed Management Options								
W$_1$-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.57 (6)	2.76 (7)	3.38 (11)	3.62 (13)	2.68 (7)	2.86 (8)	2.30 (5)	2.46 (6)
W$_2$-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.88 (8)	3.05 (9)	3.79 (14)	4.05 (16)	3.01 (9)	3.23 (10)	2.58 (6)	2.77 (7)
W$_3$-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	3.48 (12)	3.58 (12)	5.01 (25)	5.28 (28)	4.44 (19)	4.62 (21)	3.80 (14)	3.95 (15)
W$_4$-Two hand weedings	2.29 (5)	2.47 (6)	3.37 (11)	3.61 (13)	2.66 (7)	2.84 (8)	2.29 (5)	2.44 (6)
W$_5$-Weedy check	5.25 (27)	5.42 (29)	6.01 (36)	6.30 (40)	5.71 (32)	5.88 (34)	4.86 (23)	5.00 (25)
SE(m)±	***0.07***	***0.08***	***0.08***	***0.09***	***0.09***	***0.08***	***0.07***	***0.07***
C.D(P=0.05)	***0.22***	***0.25***	***0.26***	***0.28***	***0.27***	***0.25***	***0.23***	***0.22***

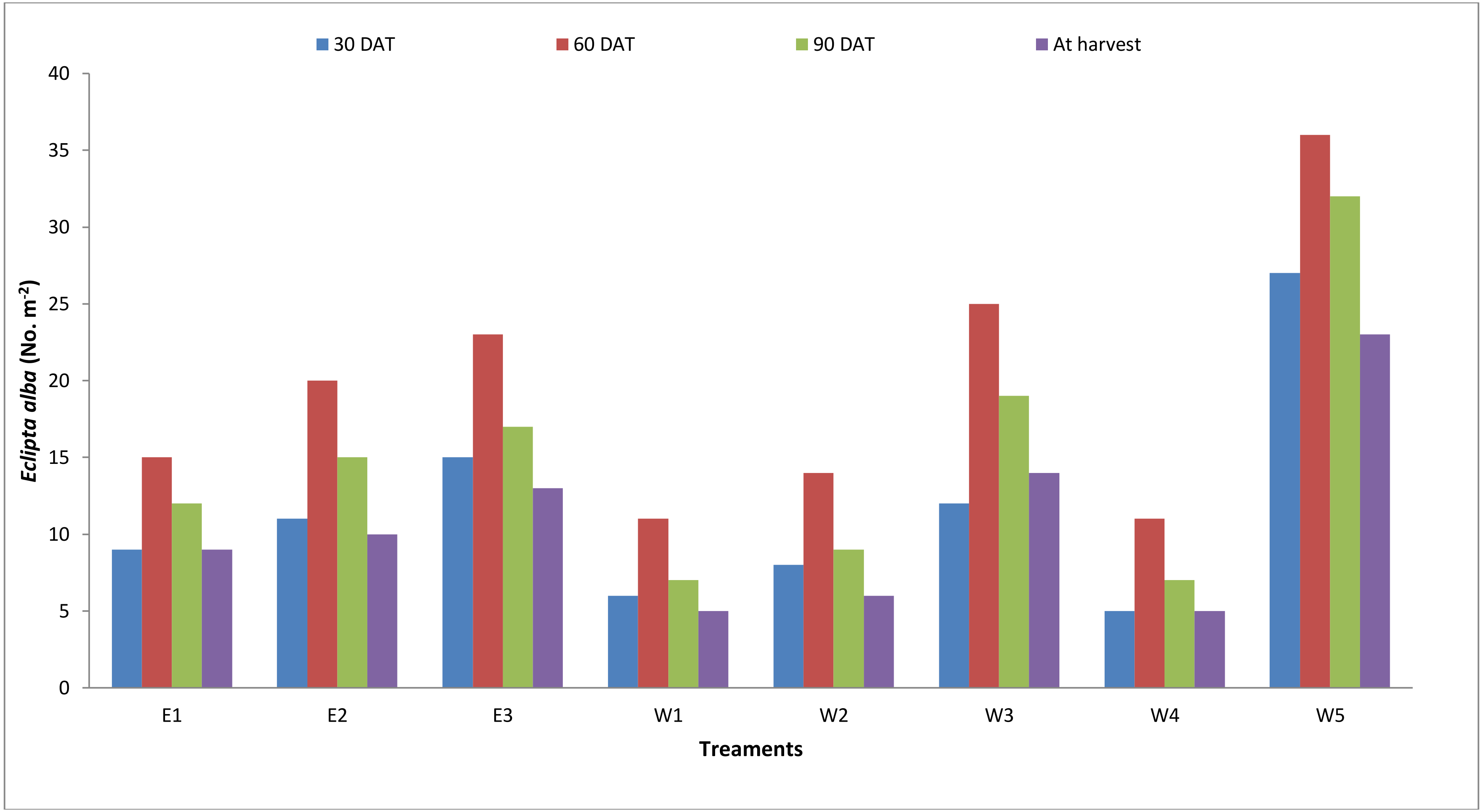


Fig.4.4 (a): Effect of establishment methods and weed management on density of *Eclipta alba* (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

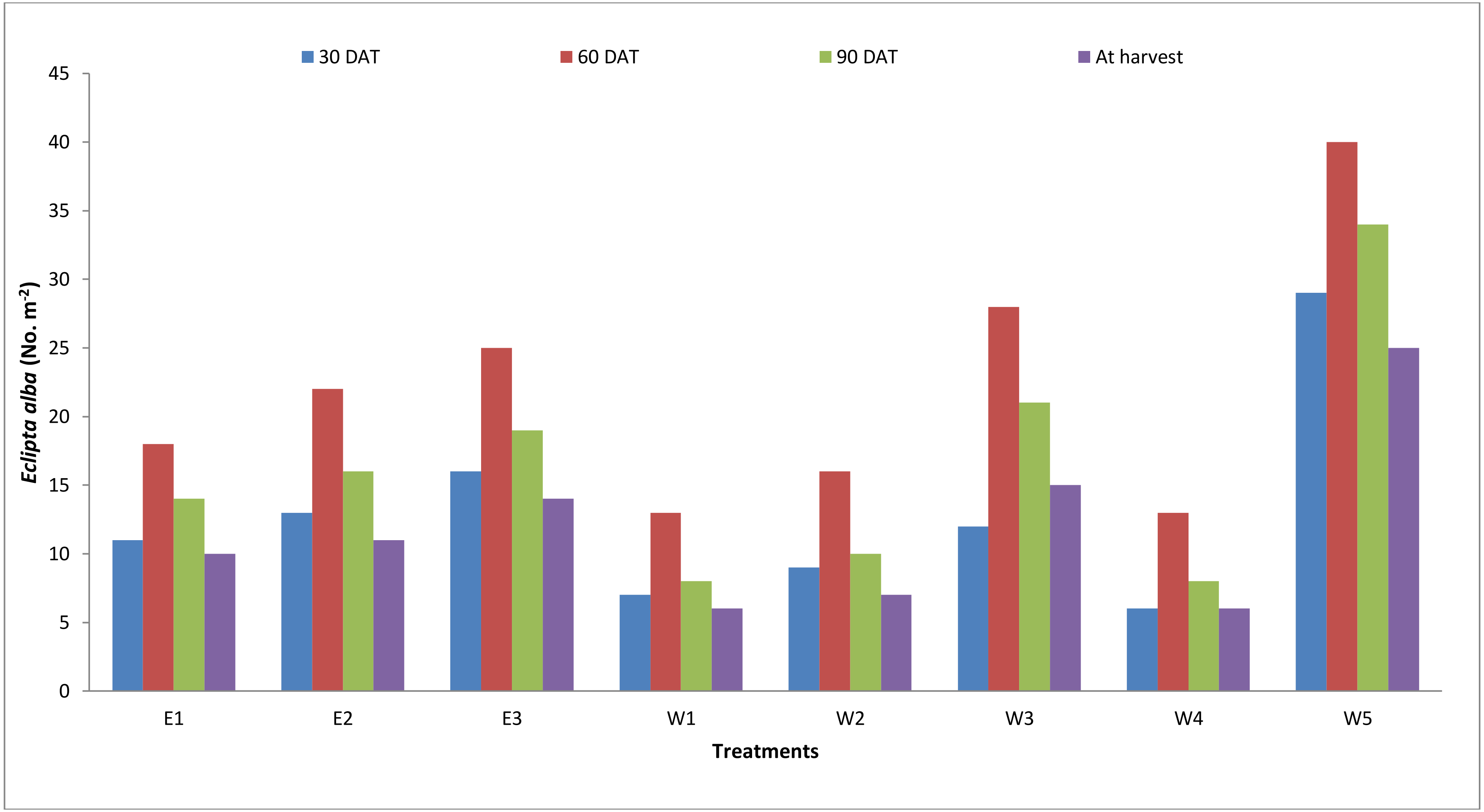


Fig.4.4 (b): Effect of establishment methods and weed management on density of *Eclipta alba* (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) was found most effective in reducing theDensity of *Cyprus rotundus* at every observation dates. At harvest, two hand weeding and Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) resulted into 59.02, 55.82and 55.49, 54.76 percent reduction intoDensity of *Cyprus rotundus* over weedy check (W_5) during 2019 and 2020, respectively.

4.1.1.3 Density of *Eclipta alba* (No. m^{-2})

The data regarding the effect of different treatments on density of *Eclipta alba* are presented in Table 4.5, depicted in Fig.4.4, and their analysis of variance is given in appendix VI.Density of *Eclipta alba* (No./m^2) at different days interval as influenced by various treatments. TheDensity of *Eclipta alba*increased at 60 DAT and there after decline with the advancement in crop growth. The effect of different crop establishment methods at different observation dates was significant. The minimumDensity of *Eclipta alba* was recorded under conventional puddled transplanting (E_1) followed by unpuddled flat (E_2) method while the maximum Density of *Eclipta alba* was recorded withfurrow irrigated raised bed method (E_3) during both the years. At harvest the percent reduction inDensity of *Eclipta alba* under conventionalpuddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 17.52, 15.74 and 9.17, 7.85 during 2019 and 2020, respectively.

The weed management practices had significant effect ondensity of*Eclipta alba*at different days interval of crop growth during both the years. Thedensity of*Eclipta alba* increased initially and reached maximum at 60 DAT under various weed management practices and their after declined at harvest. The effect of different weed management practices ondensity of *Eclipta alba* was significant and two hand weedings (W_4) was found most effective in reducingDensity of *Eclipta alba* as compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75

Table 4.6: Effect of establishment methods and weed managementon density of *Eleusine indica* (No.m^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Density of *Eleusine indica* (No.m^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	1.96 (5)	2.29 (6)	3.63 (14)	3.83 (16)	3.49 (13)	3.68 (15)	3.23 (11)	3.41 (13)
E_2-Unpuddled Flat (UPF)	3.68 (15)	3.85 (16)	4.51 (22)	4.69 (24)	4.21 (19)	4.38 (20)	3.90 (16)	4.05 (17)
E_3-Furrow Irrigated Raised Beds (FIRBs)	3.40 (13)	3.57 (14)	3.82 (16)	4.00 (17)	3.74 (15)	3.90 (16)	3.46 (13)	3.61 (14)
SE(m)±	***0.06***	***0.07***	***0.08***	***0.09***	***0.08***	***0.08***	***0.06***	***0.06***
C.D(P=0.05)	***0.23***	***0.24***	***0.30***	***0.31***	***0.29***	***0.30***	***0.22***	***0.24***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.10 (4)	2.36 (5)	2.80 (8)	2.98 (9)	2.73 (7)	2.91 (8)	2.53 (6)	2.70 (7)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.62 (7)	2.84 (8)	3.36 (11)	3.60 (13)	3.13 (9)	3.34 (11)	2.90 (8)	3.09 (9)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	2.96 (9)	3.15 (10)	4.74 (22)	4.88 (23)	4.63 (21)	4.77 (22)	4.27 (18)	4.41 (19)
W_4-Two hand weedings	1.74 (3)	2.07 (4)	2.77 (7)	2.95 (8)	2.66 (7)	2.84 (8)	2.46 (6)	2.64 (7)
W_5-Weedy check	5.65 (32)	5.77 (33)	6.26 (39)	6.45 (42)	5.92 (35)	6.09 (37)	5.47 (30)	5.62 (31)
SE(m)±	***0.07***	***0.07***	***0.08***	***0.08***	***0.09***	***0.08***	***0.07***	***0.07***
C.D(P=0.05)	***0.22***	***0.22***	***0.24***	***0.25***	***0.27***	***0.25***	***0.23***	***0.21***

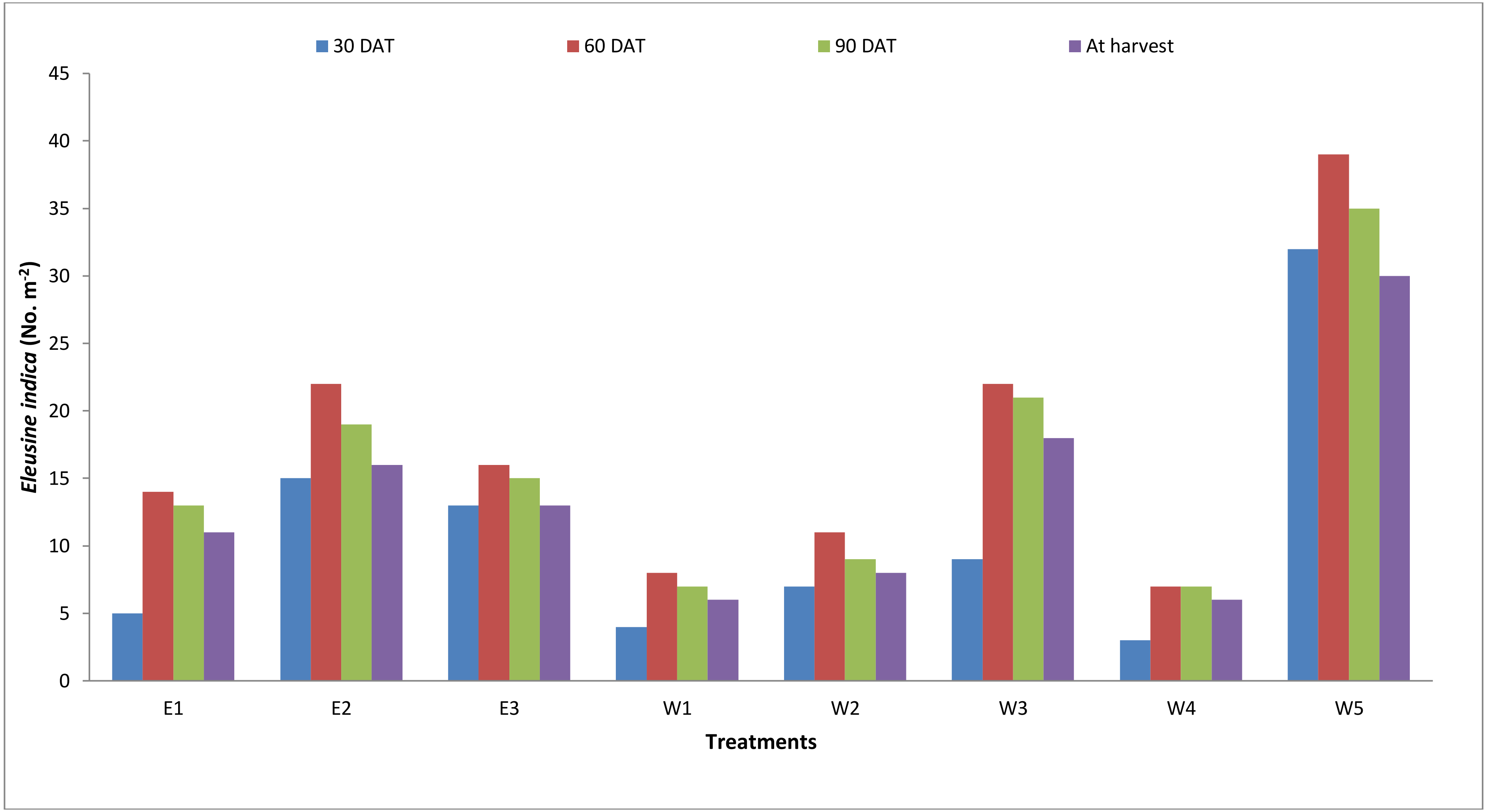


Fig.4.5 (a): Effect of establishment methods and weed management on density of *Eleusine indica* (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

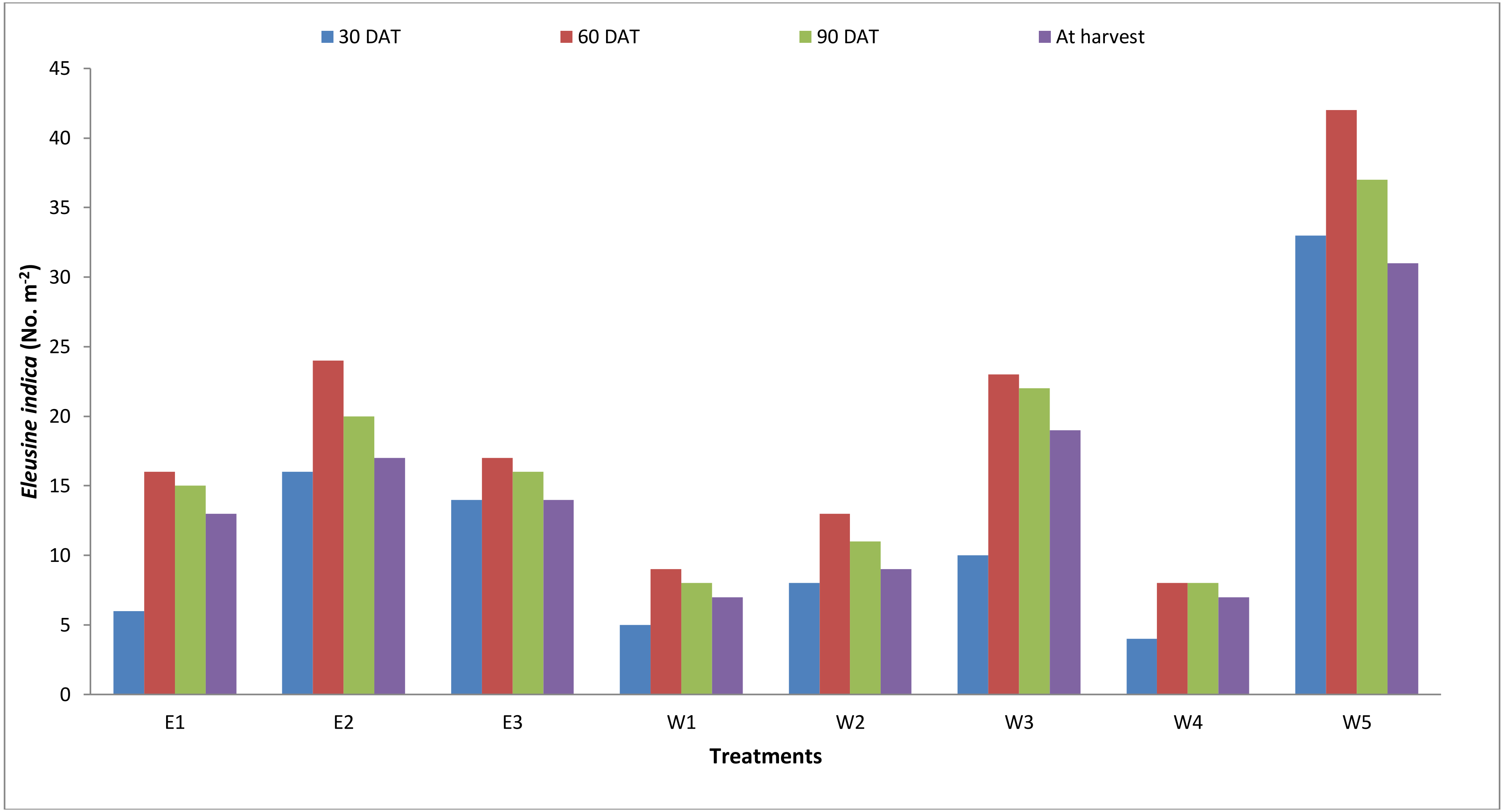


Fig.4.5 (b): Effect of establishment methods and weed management on density of *Eleusine indica* (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing theDensity of*Eclipta alba*at every observation dates. At harvest, two hand weeding (W_4) and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} resulted into 52.67, 52.88and 50.8, 51.2 percent reduction intoDensity of *Eclipta alba* over weedy check (W_5) during 2019 and 2020, respectively.

4.1.1.4 Density of *Eleusine indica* (No. m^{-2})

The data regarding the effect of different treatments on density of *Eleusine indica*are presented in Table 4.6, depicted in Fig.4.5, and their analysis of variance is given in appendix VII. Density of*Eleusine indica*(No./m^2) at different days interval as influenced by various treatments. TheDensity of *Eleusine indica*increased at 60 DAT and there after decline with the advancement in crop growth. The effect of different crop establishment methods at different observation dates was significant. The minimumDensity of *Eleusine indica*was recorded under conventionalpuddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum Density of *Eleusine indica*was recorded with unpuddled flat (E_2)method during both the years. At harvest the percent reduction inDensity of *Eleusine indica*under conventional puddled transplanting compared to furrow irrigated raised bed and unpuddled flatmethod was to 7.12, 5.54 and 17.17, 15.80 during 2019 and 2020, respectively.

The weed management practices had significant effect ondensity of*Eleusine indica* at different days interval of crop growth during both the years. Thedensity of*Eleusine indica* increased initially and reached maximum at 60 DAT under various weed management practices and there after declined at harvest. The effect of different weed management practices ondensity of*Eleusine indica* was significant and two hand weedings (W_4) was found most effective in reducingdensity of*Eleusine indica*as

Table 4.7: Effect of establishment methods and weed managementon density of *Phyllanthus niruri* (No.m^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Density of *Phyllanthus niruri* (No.m^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	2.25 (6)	2.52 (7)	3.22 (11)	3.51 (13)	3.08 (10)	3.25 (12)	2.80 (8)	2.96 (10)
E_2-Unpuddled Flat (UPF)	3.10 (11)	3.27 (12)	3.72 (14)	3.97 (17)	3.42 (13)	3.42 (13)	3.11 (10)	3.11 (11)
E_3-Furrow Irrigated Raised Beds (FIRBs)	3.23 (12)	3.39 (13)	4.17 (18)	4.18 (18)	4.05 (18)	3.93 (17)	3.68 (14)	3.62 (14)
SE(m)±	***0.06***	***0.07***	***0.07***	***0.08***	***0.06***	***0.06***	***0.06***	***0.06***
C.D(P=0.05)	***0.23***	***0.24***	***0.27***	***0.28***	***0.23***	***0.23***	***0.22***	***0.22***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.91 (3)	2.16 (4)	2.78 (7)	2.96 (8)	2.52 (6)	2.32 (5)	2.30 (5)	2.13 (4)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.30 (5)	2.51 (6)	2.97 (9)	3.14 (10)	2.84 (8)	2.96 (8)	2.59 (6)	2.70 (7)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	3.18 (10)	3.33 (11)	4.52 (20)	4.70 (22)	4.22 (17)	4.32 (18)	3.83 (14)	4.00 (16)
W_4-Two hand weedings	1.71 (3)	1.98 (4)	2.76 (7)	2.94 (8)	2.42 (5)	2.36 (5)	2.21 (5)	2.16 (4)
W_5-Weedy check	5.19 (27)	5.32 (28)	5.49 (30)	5.69 (32)	5.58 (31)	5.72 (32)	5.06 (25)	5.18 (27)
SE(m)±	***0.07***	***0.07***	***0.08***	***0.09***	***0.07***	***0.08***	***0.07***	***0.07***
C.D(P=0.05)	***0.22***	***0.22***	***0.25***	***0.26***	***0.21***	***0.23***	***0.20***	***0.21***

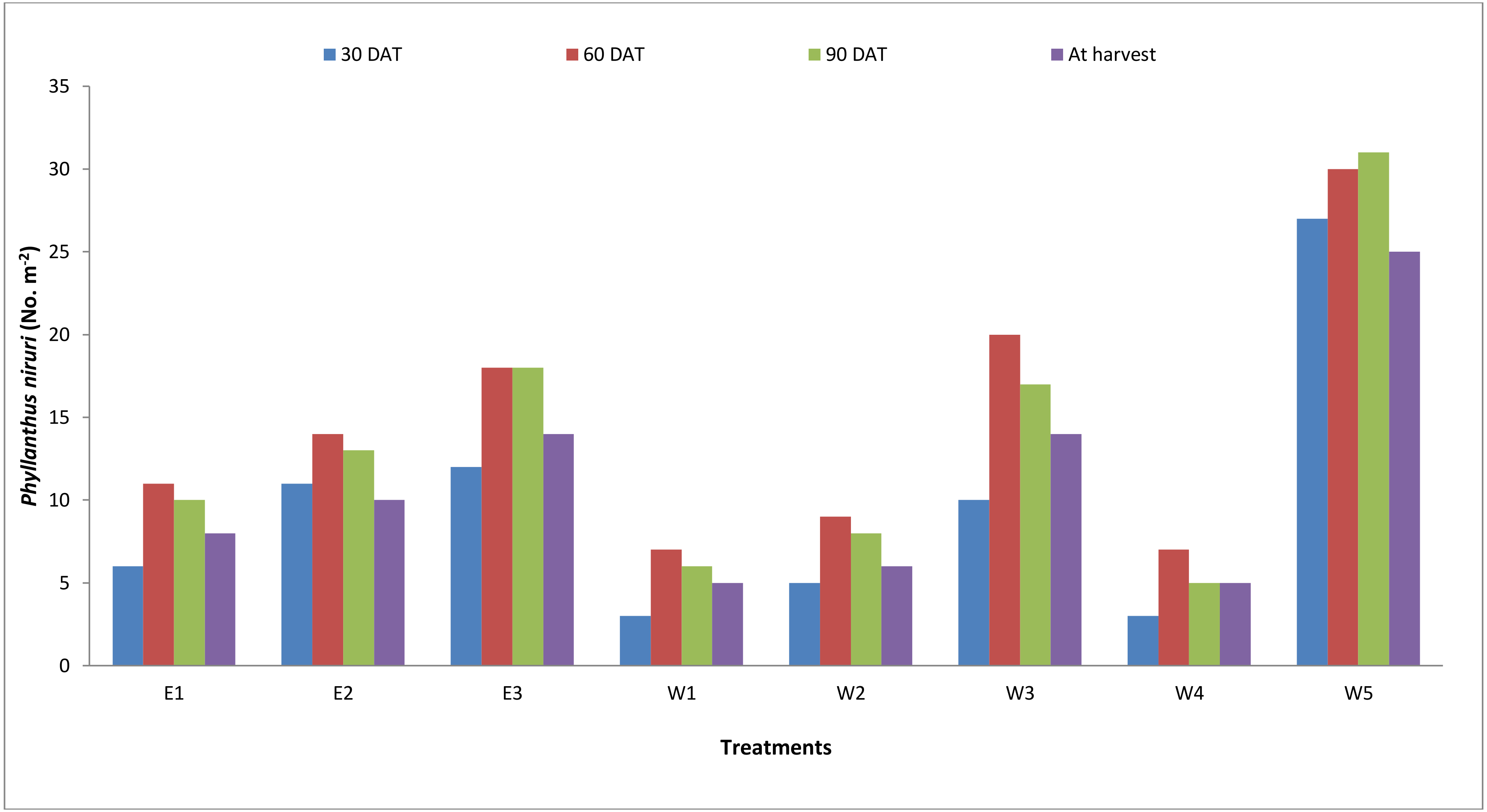


Fig. 4.6 (a): Effect of establishment methods and weed management on density of *Phyllanthus niruri* (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

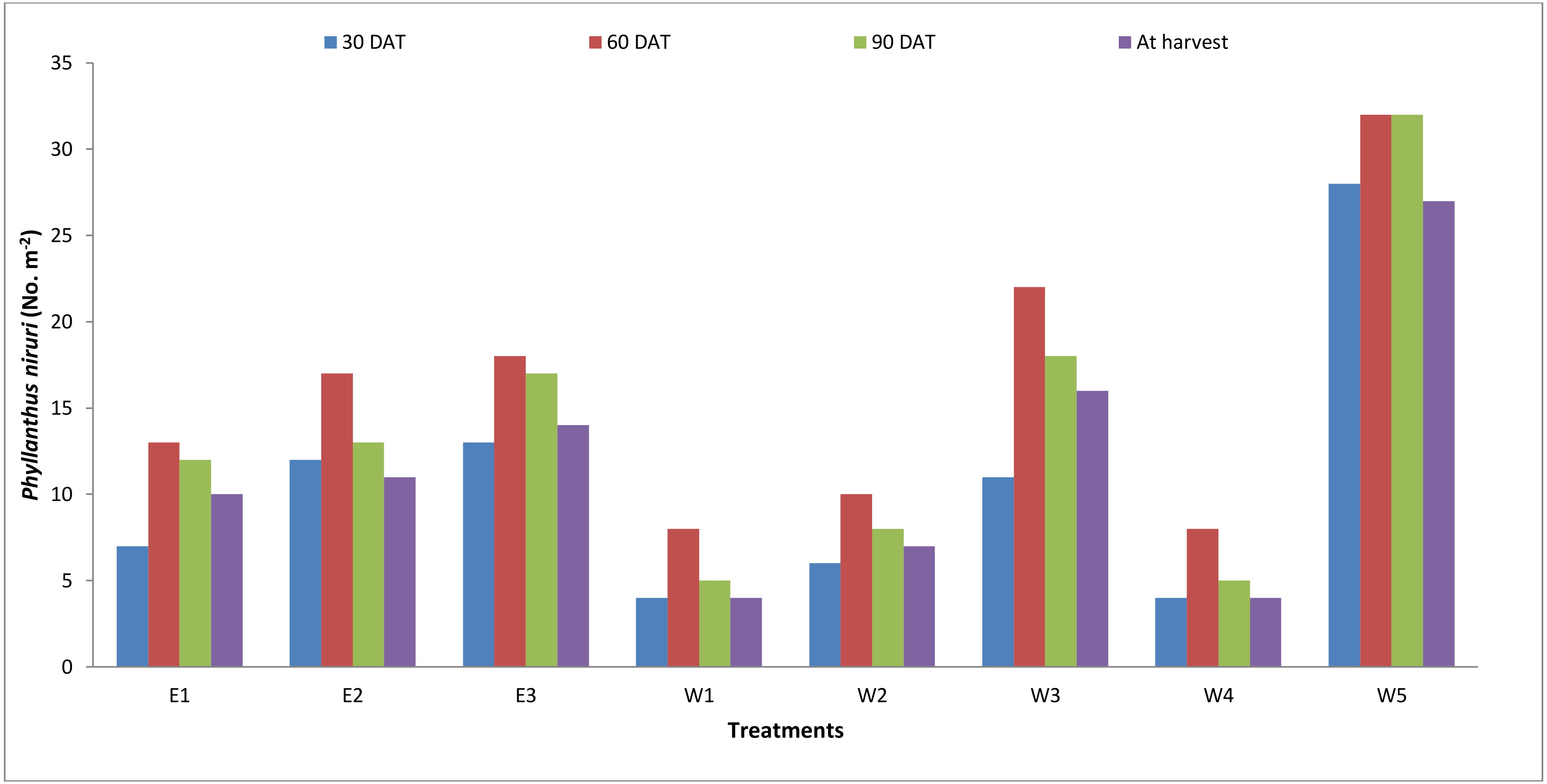


Fig. 4.6 (b): Effect of establishment methods and weed management on density of *Phyllanthus niruri* (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1)was found most effective in reducing theDensity of*Eleusine indica*at every observation dates. At harvest, two hand weeding (W_4) and Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1)resulted into 55.02, 53.02 and 53.74, 51.95 percent reduction intoDensity of*Eleusine indica*over weedy check (W_5)during 2019 and 2020, respectively.

4.1.1.5 Density of *Phyllanthus niruri* (No. m^{-2})

The data regarding the effect of different treatments on density of*Phyllanthus niruri* are presented in Table 4.7, depicted in Fig.4.6, and their analysis of variance is given in appendix VIII.Density of *Phyllanthus niruri*(No./m^2) at different days interval as influenced by various treatments. TheDensity of *Phyllanthus niruri*increased at 60 DAT and there after decline with the advancement in crop growth. The effect of different crop establishment methods at different observation dates was significant. The minimumDensity of *Phyllanthus niruri*was recorded under conventional puddled transplanting (E_1)followed by unpuddled flat (E_2)method while the maximum Density of *Phyllanthus niruri*was recorded withfurrow irrigated raised bed method (E_3) during both the years. At harvest the percent reduction inDensity of *Phyllanthus niruri*under conventionalpuddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 23.91, 18.23 and 9.96, 4.82 during 2019 and 2020, respectively.

The weed management practices had significant effect ondensity of *Phyllanthus niruri*at different days interval of crop growth during both the years. Thedensity of *Phyllanthus niruri*increased initially and reached maximum at 60 DAT under various weed management practices and there after declined at harvest. The effect of different weed management practices ondensity of *Phyllanthus niruri*was significant and two

Table 4.8: Effect of establishment methods and weed managementon density of other weed (No.m^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Density ofother weed (No.m^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	2.78 (9)	2.99 (10)	3.72 (16)	3.88 (16)	3.59 (14)	3.73 (15)	3.26 (11)	3.39 (12)
E_2-Unpuddled Flat (UPF)	3.69 (15)	3.98 (17)	4.64 (23)	4.96 (26)	4.23 (19)	4.29 (20)	3.84 (16)	3.90 (16)
E_3-Furrow Irrigated Raised Beds (FIRBs)	3.23 (12)	3.64 (14)	4.23 (20)	4.38 (21)	3.77 (15)	4.04 (18)	3.43 (13)	3.67 (15)
SE(m)±	***0.07***	***0.08***	***0.08***	***0.08***	***0.08***	***0.08***	***0.07***	***0.07***
C.D(P=0.05)	***0.26***	***0.28***	***0.28***	***0.29***	***0.29***	***0.30***	***0.25***	***0.26***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.42 (6)	2.66 (7)	3.04 (9)	3.21 (10)	2.81 (8)	2.92 (9)	2.57 (6)	2.66 (7)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.74 (7)	3.07 (9)	3.37 (11)	3.57 (12)	3.11 (9)	3.26 (10)	2.83 (8)	2.97 (8)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	3.34 (11)	3.63 (13)	5.08 (25)	5.27 (27)	4.70 (22)	4.85 (23)	4.27 (18)	4.40 (19)
W_4-Two hand weedings	2.02 (4)	2.46 (6)	2.91 (8)	3.13 (10)	2.67 (7)	2.91 (8)	2.44 (5)	2.65 (7)
W_5-Weedy check	5.67 (32)	5.87 (34)	6.58 (43)	6.85 (47)	6.01 (36)	6.16 (38)	5.45 (30)	5.58 (31)
SE(m)±	***0.07***	***0.07***	***0.08***	***0.09***	***0.09***	***0.09***	***0.08***	***0.08***
C.D(P=0.05)	***0.22***	***0.23***	***0.25***	***0.26***	***0.28***	***0.28***	***0.26***	***0.26***

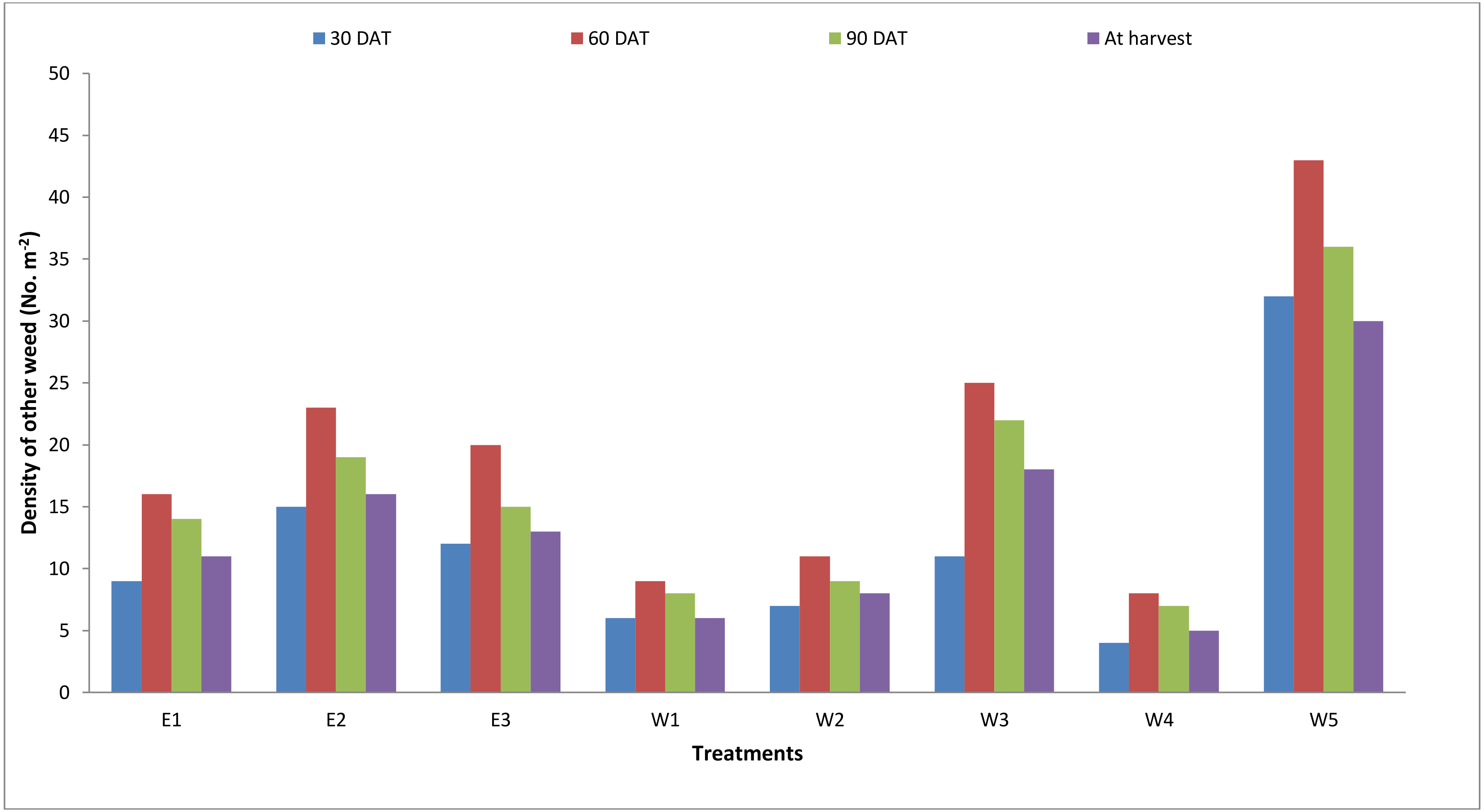


Fig.4.7 (a): Effect of establishment methods and weed management on density of other weed (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

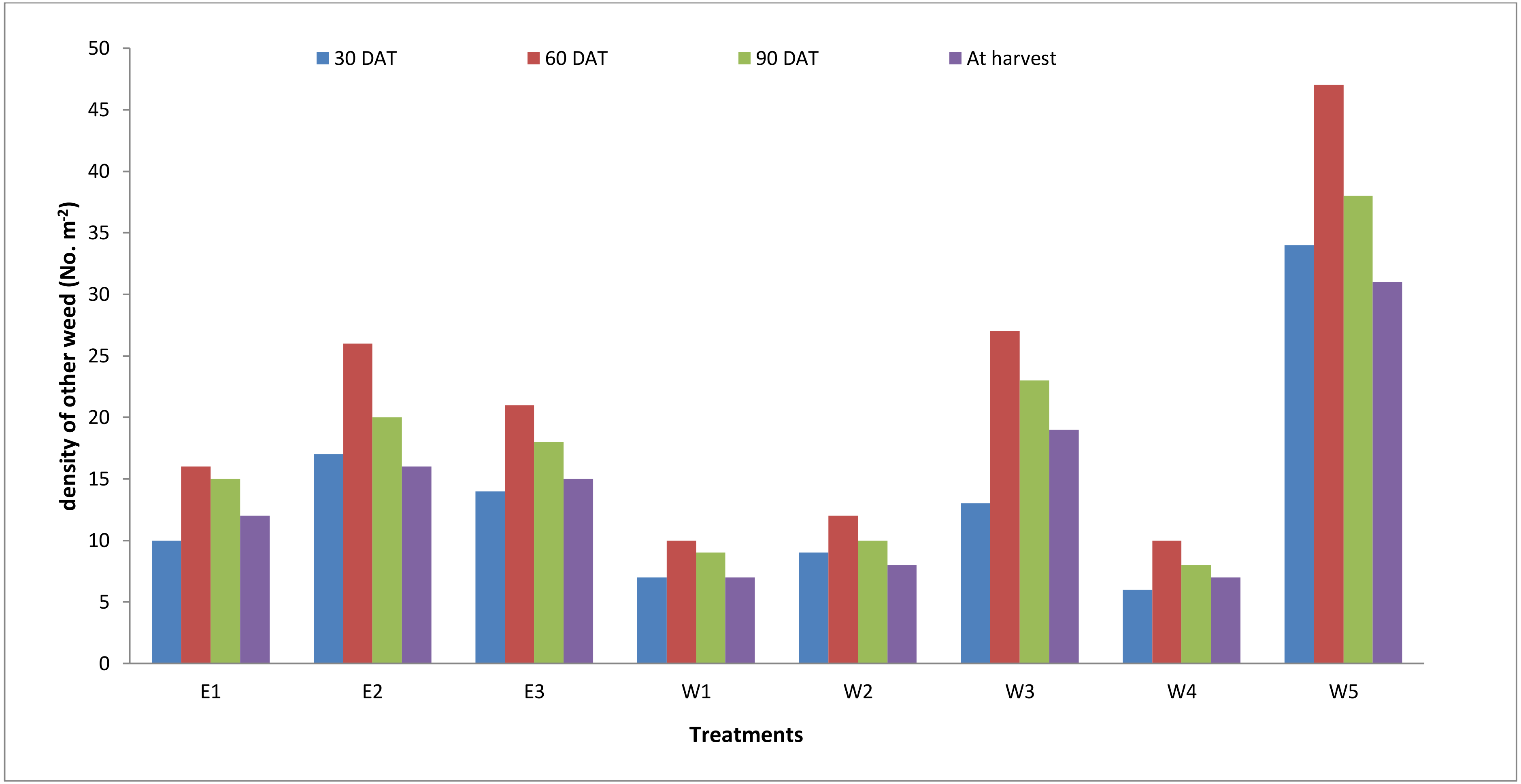


Fig.4.7 (b): Effect of establishment methods and weed management on density of other weed (No. m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

hand weedings was found most effective in reducingDensity of *Phyllanthus niruri*as compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1)was found most effective in reducing theDensity of *Phyllanthus niruri*at every observation dates. At harvest, two hand weeding (W_4) and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) resulted into 56.32, 58.30 and 50.8, 54.54, 58.88 percent reduction intoDensity of *Phyllanthus niruri*over weedy (W_5) check during 2019 and 2020, respectively.

4.1.1.6 Density of other weeds(No. m^{-2})

The data regarding the effect of different treatments on density of other weedsare presented in Table 4.8, depicted in Fig.4.7, and their analysis of variance is given in appendix IX. Density ofother weeds(No./m^2) at different days interval as influenced by various treatments. TheDensity of other weedsincreased at 60 DAT and there after decline with the advancement in crop growth. The effect of different crop establishment methods at different observation dates was significant. The minimumDensity of other weedswas recorded under conventionalpuddled transplanting(E_1) followed by furrow irrigated raised bed method (E_3) while the maximum Density ofother weedswas recorded with unpuddled flat (E_2)method during both the years. At harvest the percent reduction inDensity of other weedsunder conventional puddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flat (E_2) method was to 15.10, 13.07 and 4.95, 7.62 during 2019 and 2020, respectively.

The weed management practices had significant effect ondensity of other weedsat different days interval of crop growth during both the years. Thedensity of other weedsincreased initially and reached maximum at 60 DAT under various weed management practices and there after declined at harvest. The effect of different weed

Table 4.9: Effect of establishment methods and weed management on total weed dry weight (g m^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Total weed dry weight (g m^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	3.25 (12.82)	3.73 (15.60)	6.27 (47.69)	6.58 (50.99)	6.48 (50.82)	6.80 (54.32)	5.83 (41.26)	6.14 (44.27)
E_2-Unpuddled Flat (UPF)	4.36 (21.40)	4.70 (24.18)	8.38 (75.18)	8.59 (78.49)	8.65 (79.92)	8.86 (83.42)	7.81 (65.13)	8.01 (68.20)
E_3-Furrow Irrigated Raised Beds (FIRBs)	4.18 (20.86)	4.55 (23.64)	8.15 (72.63)	8.37 (75.93)	8.39 (76.79)	8.61 (80.29)	7.58 (62.56)	7.79 (65.61)
SE(m)±	***0.09***	***0.09***	***0.17***	***0.18***	***0.16***	***0.16***	***0.16***	***0.16***
C.D(P=0.05)	***0.31***	***0.34***	***0.61***	***0.63***	***0.56***	***0.57***	***0.56***	***0.57***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.63 (6.62)	3.12 (9.40)	5.67 (32.18)	5.96 (35.49)	5.87 (34.53)	6.16 (38.03)	5.28 (27.90)	5.56 (30.86)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	3.20 (10.06)	3.62 (12.84)	6.11 (37.86)	6.38 (41.16)	6.31 (40.55)	6.59 (44.05)	5.69 (32.84)	5.95 (35.81)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	4.58 (20.60)	4.87 (23.38)	9.28 (86.01)	9.45 (89.32)	9.53 (90.82)	9.71 (94.32)	8.61 (74.06)	8.78 (77.14)
W_4-Two hand weedings	2.20 (4.59)	2.78 (7.37)	5.11 (28.88)	5.47 (32.19)	5.31 (31.09)	5.68 (34.60)	4.78 (25.09)	5.12 (28.04)
W_5-Weedy check	7.05 (49.93)	7.25 (52.71)	11.84 (140.89)	11.98 (144.20)	12.19 (148.89)	12.33 (152.39)	11.01 (121.68)	11.16 (124.95)
SE(m)±	***0.10***	***0.10***	***0.22***	***0.20***	***0.21***	***0.20***	***0.20***	***0.19***
C.D(P=0.05)	***0.29***	***0.30***	***0.65***	***0.62***	***0.65***	***0.61***	***0.60***	***0.57***

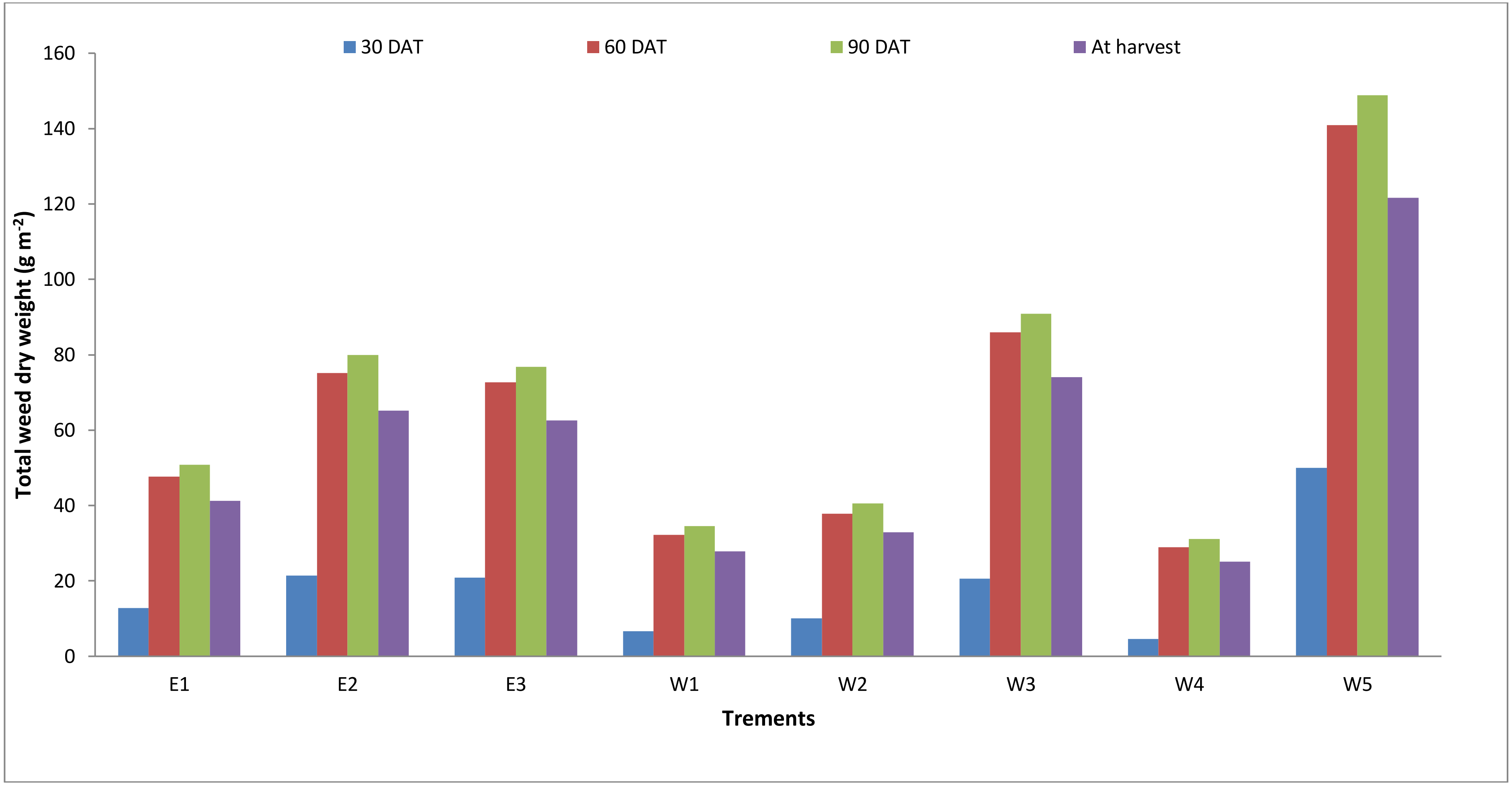


Fig.4.8 (a): Effect of establishment methods and weed management on total weed dry weight (g m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

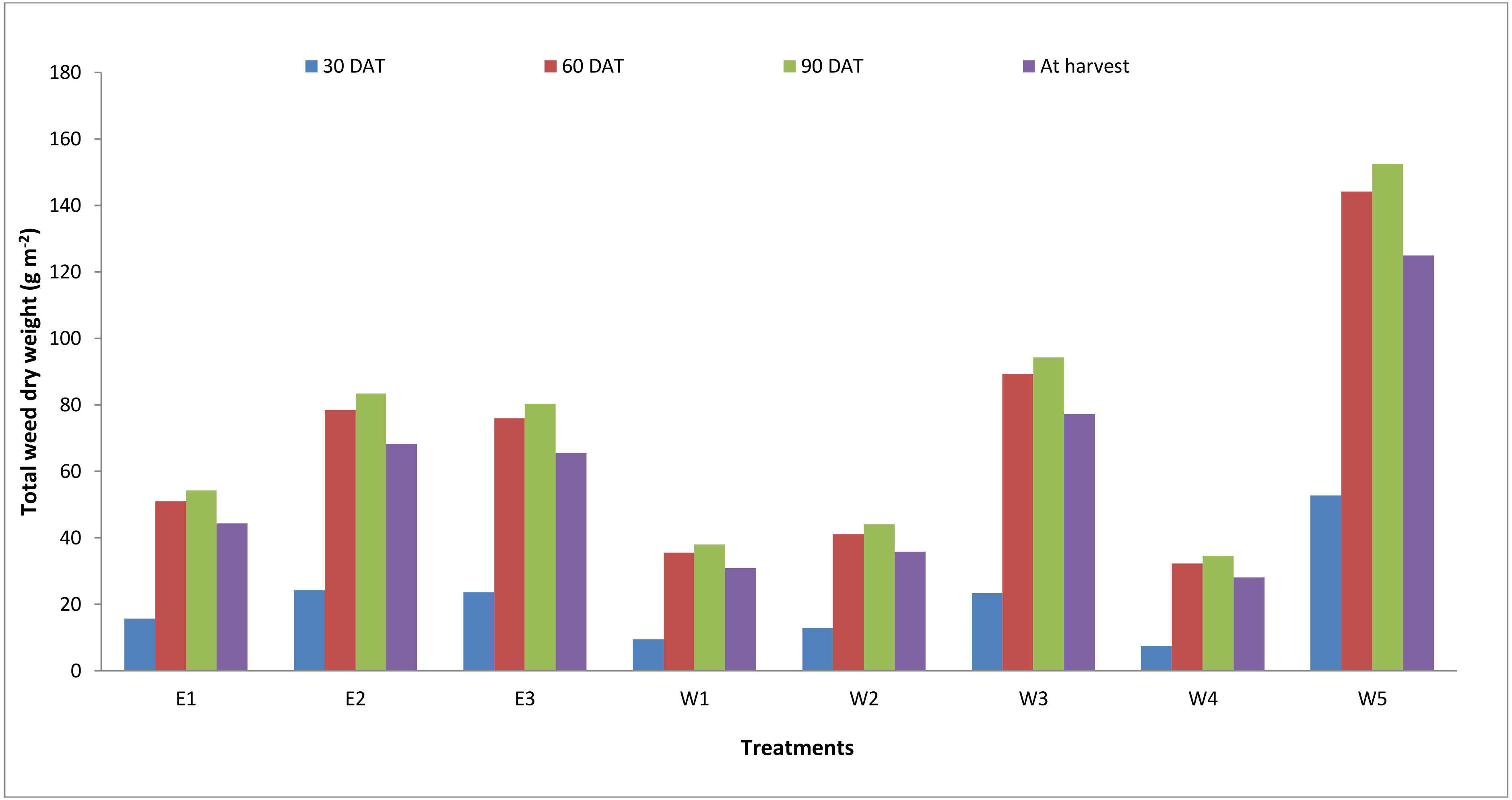


Fig.4.8 (b): Effect of establishment methods and weed management on total weed dry weight (g m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

management practices ondensity of other weedswas significant and two hand weedings (W_4) was found most effective in reducingDensity of other weedsas compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing theDensity of other weedsat every observation dates. At harvest, two hand weeding (W_4) and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) resulted into 55.22, 52.50 and 52.84, 52.32 percent reduction intoDensity of other weedsover weedy check (W_5) during 2019 and 2020, respectively.

4.1.2. Total weeds dry weight (g m^{-2})

The data regarding the effect of different treatments on dry weight of total weeds are presented in Table 4.9, depicted in Fig.4.8, and their analysis of variance is given in appendix X. The total weed dry weight increased upto 90 DAT and there after decline with the advancement in crop growth.The effect of different crop establishment methods at different observation dates was significant.The minimumdry weight of total weedswas recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum dry weight of total weeds was recorded with unpuddled flatmethod (E_2) during both the years.At harvest the percent reduction indry weight of total weedsunder conventional puddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 23.08, 21.18 and 25.35, 23.34 percent during 2019 and 2020, respectively.

The weed management practices had significant effect ondry weight of total weedsat different days interval of crop growth during both the years. Thedry weight of total weedsincreased initially and reached maximum at 90 DAT under various weed management practices and there after declined at harvest. The effect of different weed management practices ondry weight of total weedswas significant and two hand

Table 4.10: Effect of establishment methods and weed management on dry weight of *Echinocloa crusgalli L* (gm^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Dry wt. of *Echinocloa crusgalli* L(gm^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E$_1$-Conventional Puddled Transplanting (CPT)	1.67 (2.73)	1.85 (3.29)	2.28 (5.55)	2.44 (6.20)	2.54 (6.89)	2.70 (7.63)	2.22 (5.24)	2.37 (5.85)
E$_2$-Unpuddled Flat (UPF)	2.14 (4.62)	2.28 (5.18)	3.10 (9.95)	3.21 (10.60)	3.40 (11.94)	3.51 (12.69)	3.02 (9.38)	3.13 (10.00)
E$_3$-Furrow Irrigated Raised Beds (FIRBs)	1.95 (4.27)	2.11 (4.82)	2.78 (7.76)	2.90 (8.41)	3.06 (9.43)	3.18 (10.17)	2.71 (7.32)	2.82 (7.93)
SE(m)±	***0.03***	***0.04***	***0.05***	***0.06***	***0.05***	***0.06***	***0.05***	***0.06***
C.D(P=0.05)	***0.13***	***0.14***	***0.20***	***0.20***	***0.20***	***0.21***	***0.20***	***0.20***
(W) Weed Management Options								
W$_1$-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.30 (1.24)	1.50 (1.80)	2.05 (3.72)	2.20 (4.37)	2.29 (4.78)	2.45 (5.53)	2.00 (3.51)	2.15 (4.13)
W$_2$-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.70 (2.43)	1.86 (2.99)	2.21 (4.52)	2.35 (5.17)	2.46 (5.70)	2.61 (6.45)	2.15 (4.27)	2.29 (4.88)
W$_3$-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	2.17 (4.24)	2.30 (4.79)	3.22 (9.96)	3.32 (10.61)	3.51 (11.95)	3.62 (12.70)	3.13 (9.39)	3.23 (10.00)
W$_4$-Two hand weedings	1.12 (0.78)	1.35 (1.34)	2.02 (3.98)	2.19 (4.63)	2.27 (5.07)	2.44 (5.82)	1.97 (3.75)	2.14 (4.36)
W$_5$-Weedy check	3.31 (10.68)	3.40 (11.24)	4.11 (16.59)	4.19 (17.24)	4.46 (19.58)	4.54 (20.33)	3.99 (15.65)	4.07 (16.26)
SE(m)±	***0.06***	***0.06***	***0.08***	***0.08***	***0.08***	***0.08***	***0.08***	***0.07***
C.D(P=0.05)	***0.20***	***0.20***	***0.25***	***0.24***	***0.25***	***0.24***	***0.24***	***0.23***

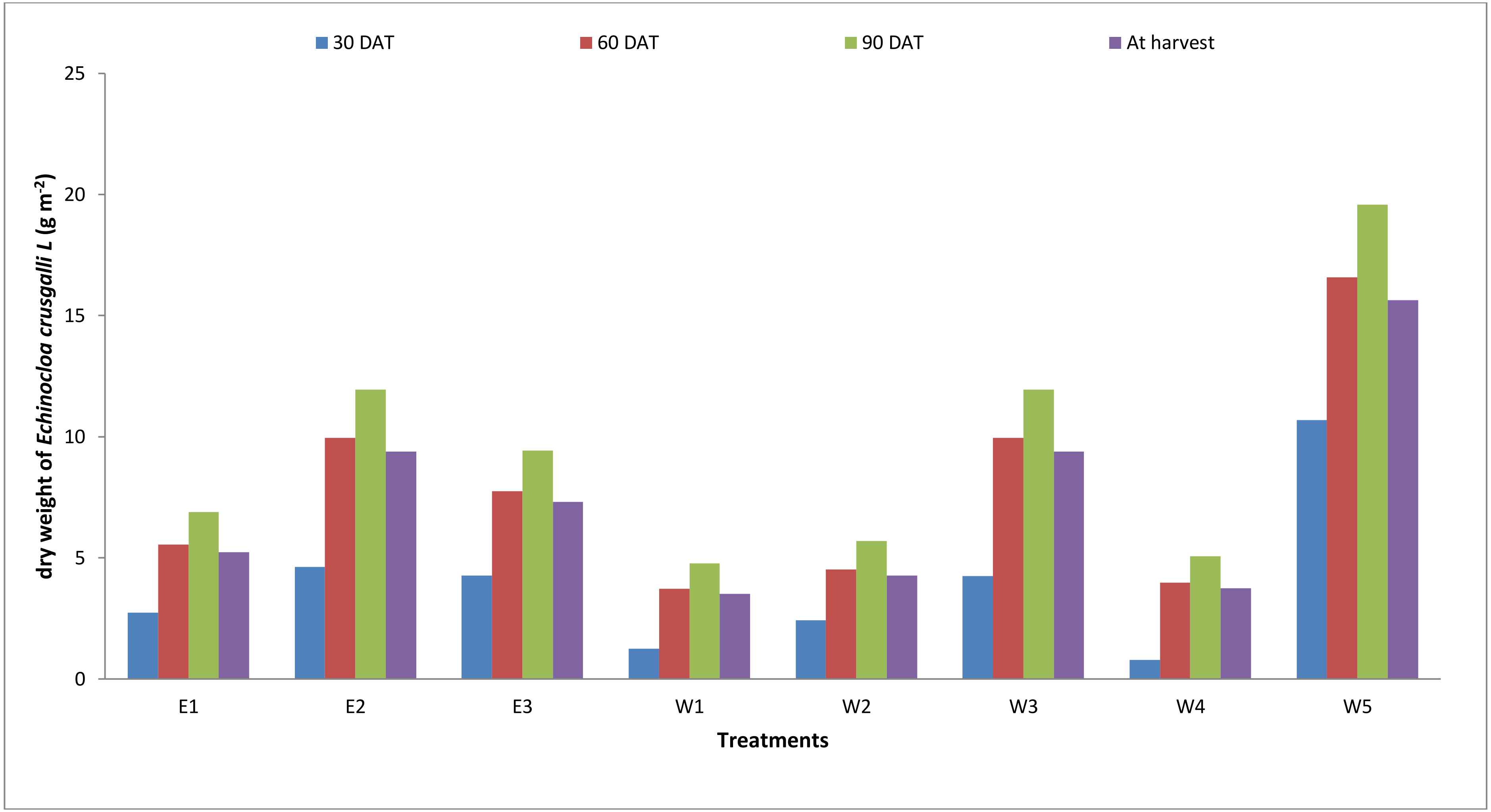


Fig.4.9 (a): Effect of establishment methods and weed management on dry weight of *Echinocloa crusgalli L* (g m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

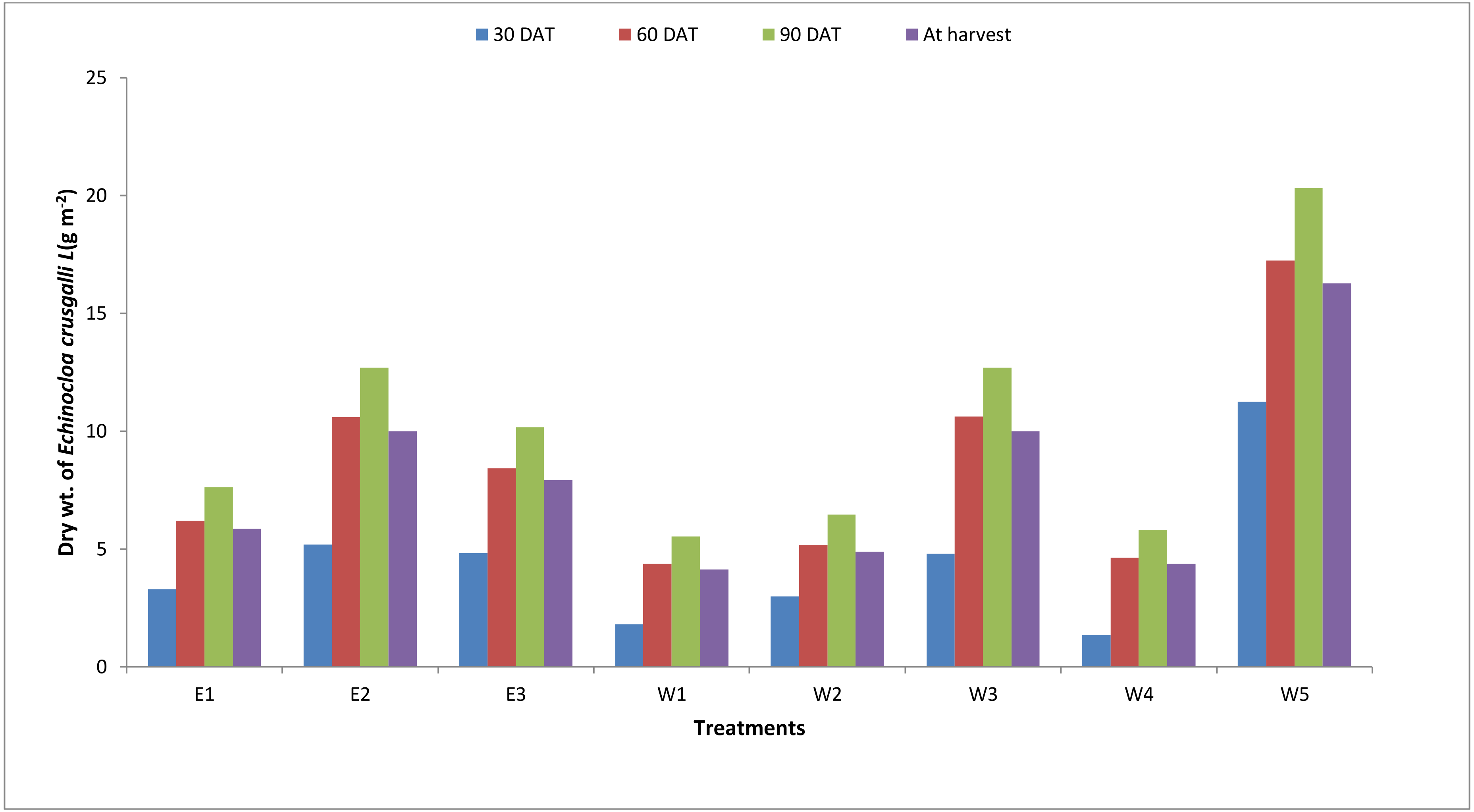


Fig.4.9 (b): Effect of establishment methods and weed management on dry weight of *Echinocloa crusgalli L* (g m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

weedings (W_4) was found most effective in reducingdry weight of total weedsas compared to rest of the weed management practices. Among the herbicides, application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing thedry weight of total weedsat every observation dates. At harvest, two hand weeding(W_4) and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) resulted into 56.58, 54.12 and 52.04, 50.17 percent reduction intodry weight of total weedsover weedy check (W_5) during 2019 and 2020, respectively.

4.1.2.1*Echinochloa crusgalli*(L)dry weight(g m^{-2})

The data regarding the effect of different treatments on dry weight of*Echinochloa crusgalli*(L)are presented in Table 4.10, depicted in Fig. 4.9, and their analysis of variance is given in appendix XI. The *Echinochloa crusgalli*(L)dry weight increased at 90 DAT and there after decline with the advancement in crop growth.The effect of different crop establishment methods at different observation dates was significant.The minimumdry weight of *Echinochloa crusgalli*(L) was recorded under conventional puddled transplanting(E_1) followed by furrow irrigated raised bed method (E_3) while the maximum dry weight of *Echinochloa crusgalli*(L) was recorded with unpuddled flatmethod(E_2) during both the years. The percent reduction indry weight of *Echinochloa crusgalli*(L)under conventional puddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 18.08, 15.95 and 26.49, 24.28 during 2019 and 2020, respectively.

The weed management practices had significant effect ondry weight of *Echinochloa crusgalli*(L)at different days interval of crop growth during both the years. Thedry weight of *Echinochloa crusgalli*(L)increased initially and reached maximum at 90 DAT under various weed management practices and there after declined at harvest. The effect of different weed management practices ondry weight of *Echinochloa*

Table 4.11: Effect of establishment methods and weed management on dry weight of *Cyprus rotundus*L (gm^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Dry wt. of *Cyprus rotundus* L (gm^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	1.50 (2.19)	1.58 (2.41)	2.91 (10.83)	3.03 (11.35)	3.21 (12.95)	3.33 (13.55)	2.93 (10.62)	3.05 (11.25)
E_2-Unpuddled Flat (UPF)	1.97 (3.91)	2.03 (4.13)	4.04 (16.99)	4.11 (17.51)	4.38 (20.04)	4.45 (20.64)	3.98 (16.43)	4.07 (17.13)
E_3-Furrow Irrigated Raised Beds (FIRBs)	1.82 (3.73)	1.89 (3.95)	3.69 (14.59)	3.76 (15.11)	4.01 (17.28)	4.09 (17.88)	3.65 (14.17)	3.74 (14.84)
SE(m)±	***0.03***	***0.04***	***0.06***	***0.07***	***0.08***	***0.08***	***0.07***	***0.07***
C.D(P=0.05)	***0.13***	***0.14***	***0.24***	***0.24***	***0.30***	***0.30***	***0.26***	***0.27***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.24 (1.09)	1.33 (1.31)	2.58 (6.43)	2.68 (6.95)	2.84 (7.89)	2.95 (8.49)	2.59 (6.47)	2.70 (7.05)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.33 (1.31)	1.41 (1.53)	2.75 (7.48)	2.85 (8.00)	3.02 (9.10)	3.12 (9.70)	2.75 (7.46)	2.86 (8.05)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	2.02 (3.64)	2.08 (3.86)	4.21 (17.29)	4.27 (17.81)	4.56 (20.38)	4.62 (20.98)	4.14 (16.71)	4.22 (17.41)
W_4-Two hand weedings	1.05 (0.62)	1.15 (0.84)	2.38 (6.01)	2.50 (6.53)	2.65 (7.41)	2.78 (8.01)	2.42 (6.08)	2.55 (6.65)
W_5-Weedy check	3.17 (9.72)	3.20 (9.94)	5.82 (33.48)	5.87 (34.00)	6.27 (39.00)	6.32 (39.60)	5.69 (31.98)	5.76 (32.86)
SE(m)±	***0.06***	***0.06***	***0.13***	***0.12***	***0.13***	***0.13***	***0.12***	***0.12***
C.D(P=0.05)	***0.18***	***0.18***	***0.38***	***0.36***	***0.41***	***0.39***	***0.36***	***0.35***

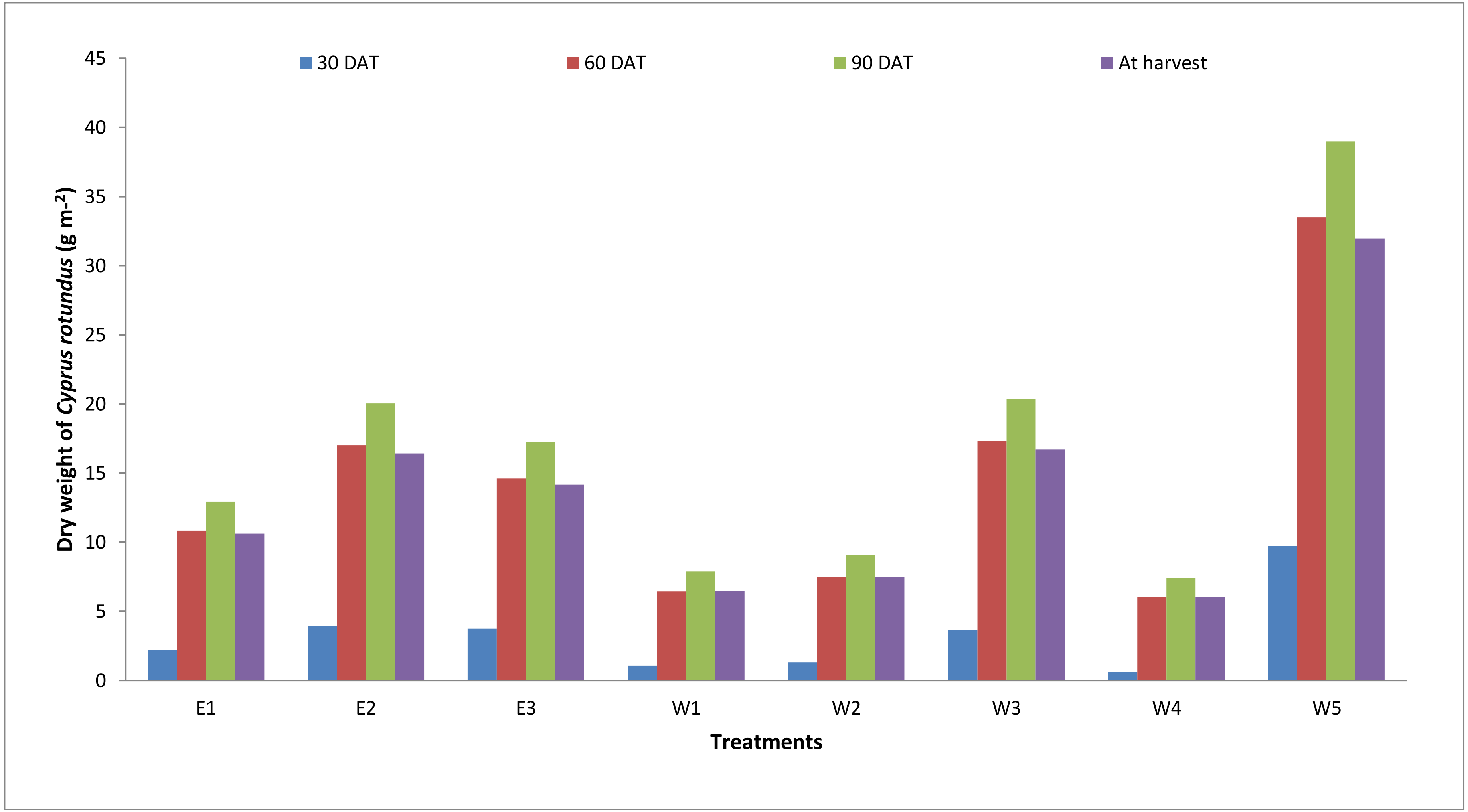


Fig.4.10 (a): Effect of establishment methods and weed management on dry weight of *Cyprus rotundus* (g m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

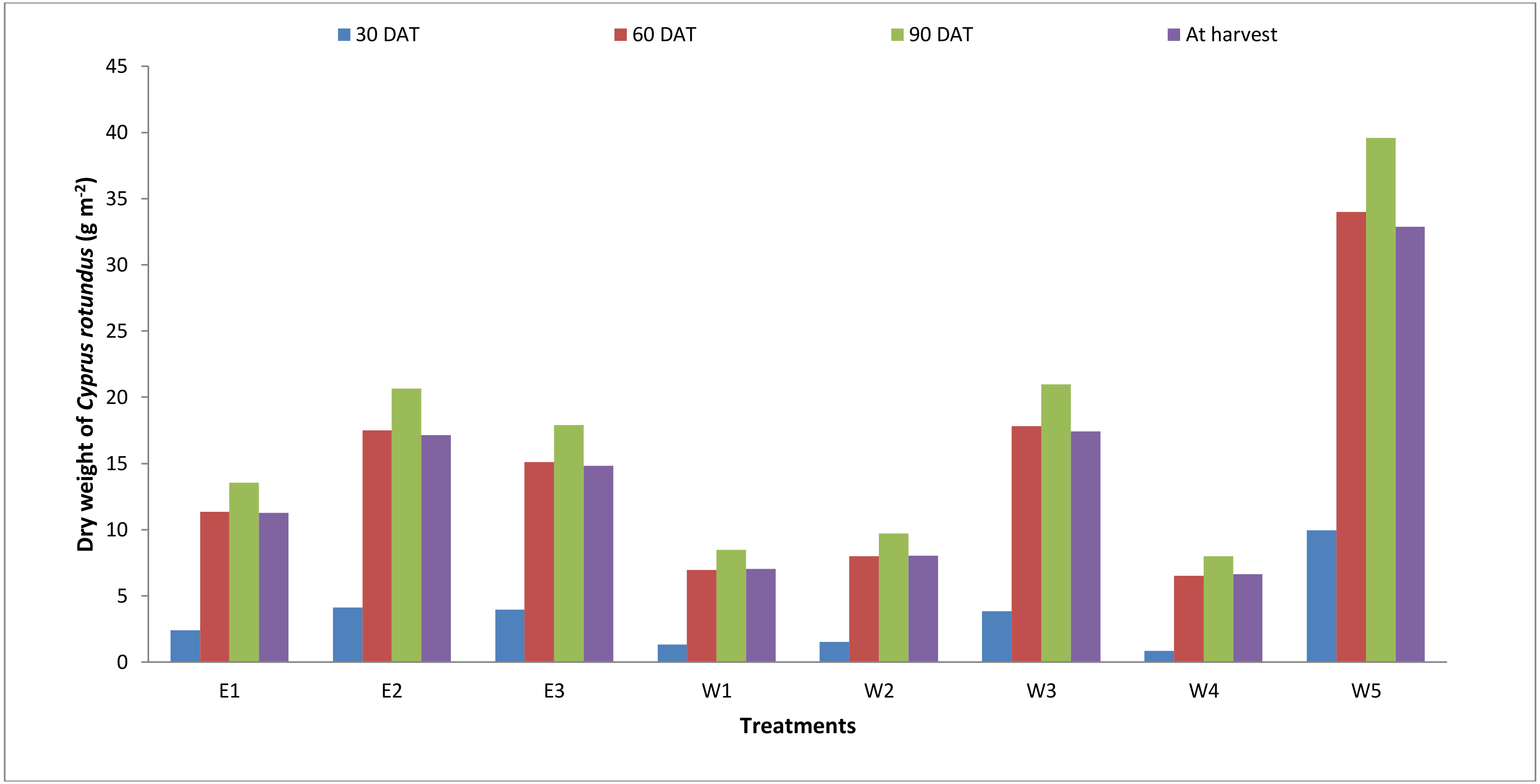


Fig. 4.10 (b): Effect of establishment methods and weed management on dry weight of *Cyprus rotundus* (g m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

crusgalli(L)was significant and two hand weedings (W_4) was found most effective in reducingdry weight of *Echinochloa crusgalli*(L)as compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing thedry weight of *Echinochloa crusgalli*(L) at every observation dates. At harvest, two hand weeding and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) resulted into 50.62, 47.42 and 49.87, 47.17 percent reduction intodry weight of *Echinochloa crusgalli*(L)over weedy check (W_5) during 2019 and 2020, respectively.

4.1.2.2*Cyprus rotundus*(L)dry weight(g m^{-2})

The data regarding the effect of different treatments on dry weight of*Cyprus rotundus*(L)are presented in Table 4.11, depicted in Fig.4.10, and their analysis of variance is given in appendix XII. The*Cyprus rotundus*(L)dry weight increased at 90 DAT and there after decline with the advancement in crop growth.The effect of different crop establishment methods at different observation dates was significant.The minimumdry weight of*Cyprus rotundus* was recorded under conventionalpuddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum dry weight of *Cyprus rotundus*(L)was recorded with unpuddled flatmethod (E_2) during both the years.At harvest the percent reduction indry weight of *Cyprus rotundus*(L)under conventionalpuddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 19.72, 18.44 and 26.38, 25.06 during 2019 and 2020, respectively.

The weed management practices had significant effect ondry weight of*Cyprus rotundus*(L)at different days interval of crop growth during both the years. Thedry weight of *Cyprus rotundus*(L) increased initially and reached maximum at 90 DAT under various weed management practices and there after declined at harvest. The effect

Table 4.12: Effect of establishment methods and weed management on dry weight of *Eclipta alba*(gm^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Dry wt. of *Eclipta alba* (gm^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	1.51 (1.99)	1.53 (2.06)	2.39 (6.82)	2.51 (7.26)	2.57 (8.02)	2.70 (8.54)	2.35 (6.58)	2.47 (7.00)
E_2-Unpuddled Flat (UPF)	1.57 (2.28)	1.61 (2.39)	3.00 (9.19)	3.07 (9.63)	3.23 (10.81)	3.32 (11.33)	2.95 (8.86)	3.02 (9.29)
E_3-Furrow Irrigated Raised Beds (FIRBs)	1.94 (3.70)	1.97 (3.81)	3.58 (12.96)	3.64 (13.40)	3.87 (15.25)	3.94 (15.77)	3.52 (12.50)	3.58 (12.93)
SE(m)±	***0.02***	***0.02***	***0.06***	***0.06***	***0.06***	***0.07***	***0.05***	***0.05***
C.D(P=0.05)	***0.09***	***0.10***	***0.21***	***0.21***	***0.24***	***0.24***	***0.19***	***0.20***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.26 (1.11)	1.30 (1.22)	2.34 (5.22)	2.43 (5.67)	2.51 (6.15)	2.62 (6.67)	2.30 (5.04)	2.39 (5.47)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.33 (1.29)	1.37 (1.40)	2.52 (6.16)	2.61 (6.60)	2.72 (7.24)	2.82 (7.76)	2.48 (5.94)	2.57 (6.36)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	1.92 (3.24)	1.95 (3.35)	3.69 (13.19)	3.75 (13.63)	3.99 (15.52)	4.06 (16.04)	3.62 (12.72)	3.68 (13.05)
W_4-Two hand weedings	1.22 (1.01)	1.23 (1.06)	1.94 (4.09)	2.08 (4.53)	2.07 (4.81)	2.23 (5.33)	1.91 (3.95)	2.05 (4.37)
W_5-Weedy check	2.64 (6.64)	2.66 (6.75)	4.46 (19.62)	4.51 (20.06)	4.83 (23.08)	4.88 (23.60)	4.38 (18.92)	4.43 (19.35)
SE(m)±	***0.04***	***0.04***	***0.11***	***0.11***	***0.12***	***0.11***	***0.11***	***0.10***
C.D(P=0.05)	***0.14***	***0.14***	***0.34***	***0.32***	***0.37***	***0.34***	***0.34***	***0.32***

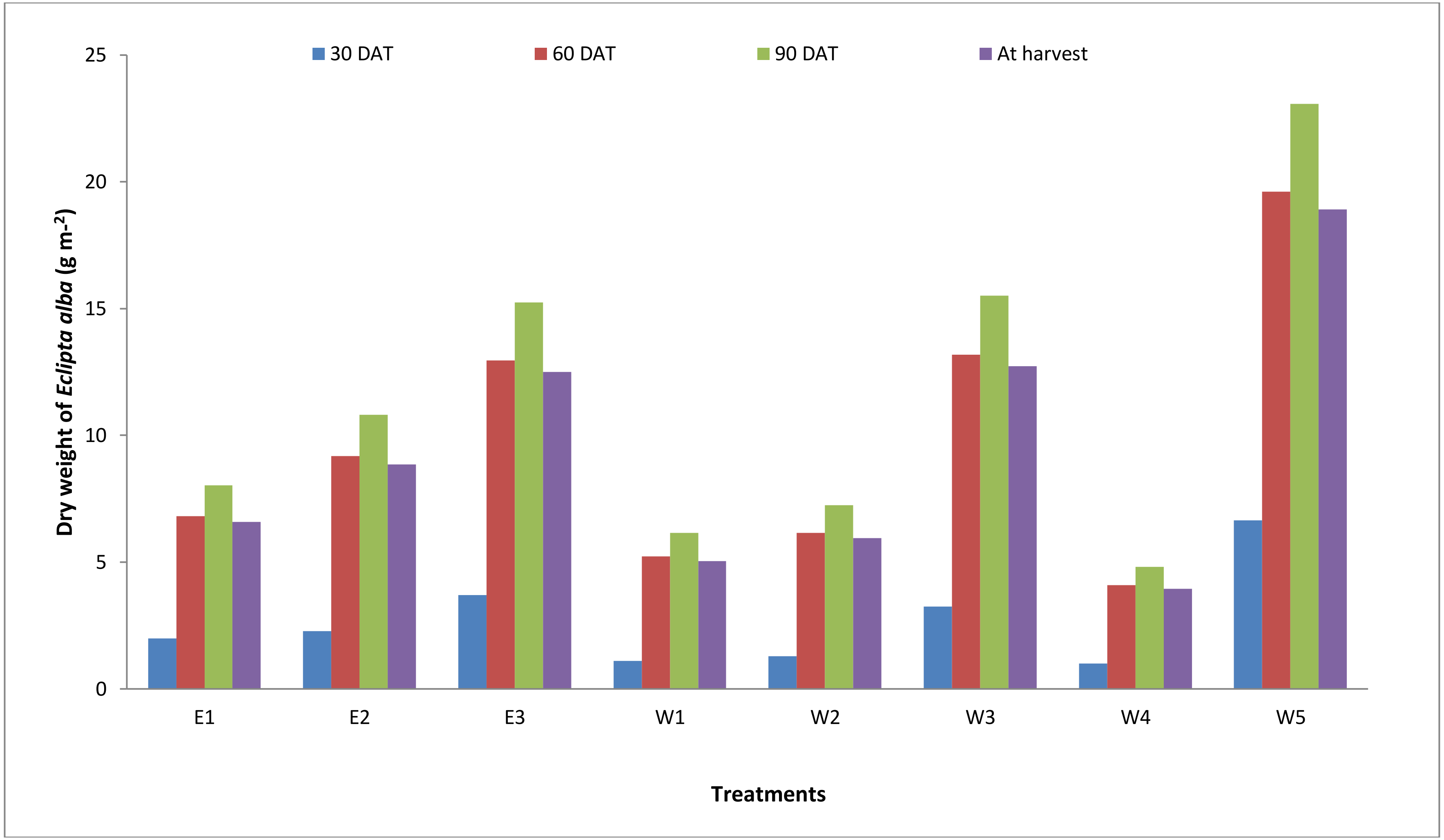


Fig.4.11 (a): Effect of establishment methods and weed management on dry weight of *Eclipta alba* (g m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

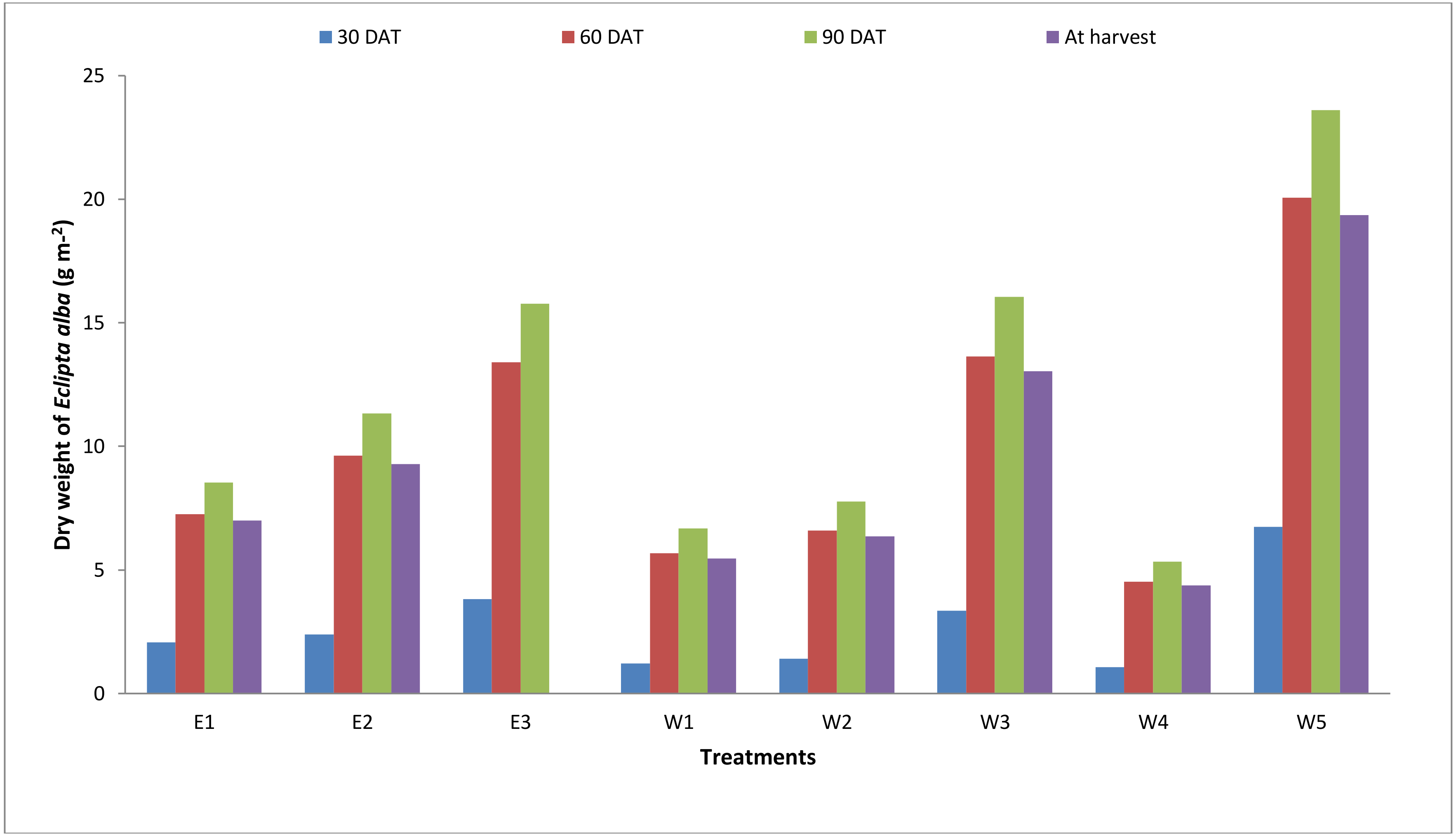


Fig.4.11 (b): Effect of establishment methods and weed management on dry weight of *Eclipta alba* (g m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

of different weed management practices ondry weight of *Cyprus rotundus*(L)was significant and two hand weedings (W_4) was found most effective in reducingdry weight of*Cyprus rotundus*(L)as compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing thedry weight of*Cyprus rotundus*(L)at every observation dates. At harvest, two hand weeding and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) resulted into 57.46, 55.72 and 54.48, 53.12 percent reduction intodry weight of*Cyprus rotundus*(L) over weedy check (W_5) during 2019 and 2020, respectively.

4.1.2.3*Eclipta alba* dry weight(g m^{-2})

The data regarding the effect of different treatments on dry weight of *Eclipta alba*are presented in Table 4.12, depicted in Fig.4.11, and their analysis of variance is given in appendix XIII. The*Eclipta alba*dry weight increased at 90 DAT and there after decline with the advancement in crop growth.The effect of different crop establishment methods at different observation dates was significant.The minimumdry weight of*Eclipta alba*was recorded under conventional puddled transplanting (E_1) followed byunpuddled flat(E_2) method while the maximum dry weight of *Eclipta alba*was recorded with furrow irrigated raised bed method (E_3) during both the years.At harvest the percent reduction indry weight of*Eclipta alba*under conventionalpuddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 33.23, 31.00 and 20.33, 18.21 during 2019 and 2020, respectively.

The weed management practices had significant effect ondry weight of*Eclipta alba*at different days interval of crop growth during both the years. Thedry weight of

*Eclipta alba*increased initially and reached maximum at 90 DAT under various weed management practices and there after declined at harvest. The effect of different weed

Table 4.13: Effect of establishment methods and weed management on dry weight of *Eleusine indica*(gm^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Dry wt. of *Eleusine indica* (gm^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	1.41 (1.98)	1.56 (2.36)	2.62 (7.18)	2.75 (7.79)	2.80 (8.26)	2.93 (8.96)	2.55 (6.77)	2.67 (7.35)
E_2-Unpuddled Flat (UPF)	1.97 (3.65)	2.07 (4.03)	3.52 (12.75)	3.61 (13.36)	3.77 (14.66)	3.87 (15.36)	3.43 (12.02)	3.51 (12.60)
E_3-Furrow Irrigated Raised Beds (FIRBs)	1.89 (3.46)	2.00 (3.84)	3.07 (10.20)	3.18 (10.81)	3.28 (11.73)	3.40 (12.43)	2.99 (9.62)	3.10 (10.19)
SE(m)±	***0.03***	***0.03***	***0.06***	***0.06***	***0.06***	***0.06***	***0.06***	***0.06***
C.D(P=0.05)	***0.12***	***0.13***	***0.22***	***0.23***	***0.21***	***0.22***	***0.22***	***0.23***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.24 (1.16)	1.39 (1.54)	2.31 (5.02)	2.44 (5.63)	2.46 (5.77)	2.60 (6.47)	2.25 (4.73)	2.38 (5.31)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.55 (1.04)	1.68 (2.42)	2.54 (6.11)	2.66 (6.72)	2.71 (7.03)	2.84 (7.73)	2.47 (5.76)	2.59 (6.34)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	2.00 (3.56)	2.09 (3.94)	3.73 (13.54)	3.81 (14.15)	3.99 (15.57)	4.08 (16.27)	3.63 (12.76)	3.71 (13.34)
W_4-Two hand weedings	1.21 (1.01)	1.36 (1.39)	2.17 (4.40)	2.31 (5.01)	2.30 (5.06)	2.46 (5.76)	2.11 (4.15)	2.25 (4.73)
W_5-Weedy check	2.80 (7.37)	2.86 (7.75)	4.62 (21.14)	4.68 (21.75)	4.94 (24.31)	5.01 (25.02)	4.49 (19.94)	4.55 (20.51)
SE(m)±	***0.05***	***0.04***	***0.08***	***0.08***	***0.09***	***0.09***	***0.08***	***0.08***
C.D(P=0.05)	***0.14***	***0.14***	***0.25***	***0.25***	***0.28***	***0.27***	***0.24***	***0.24***

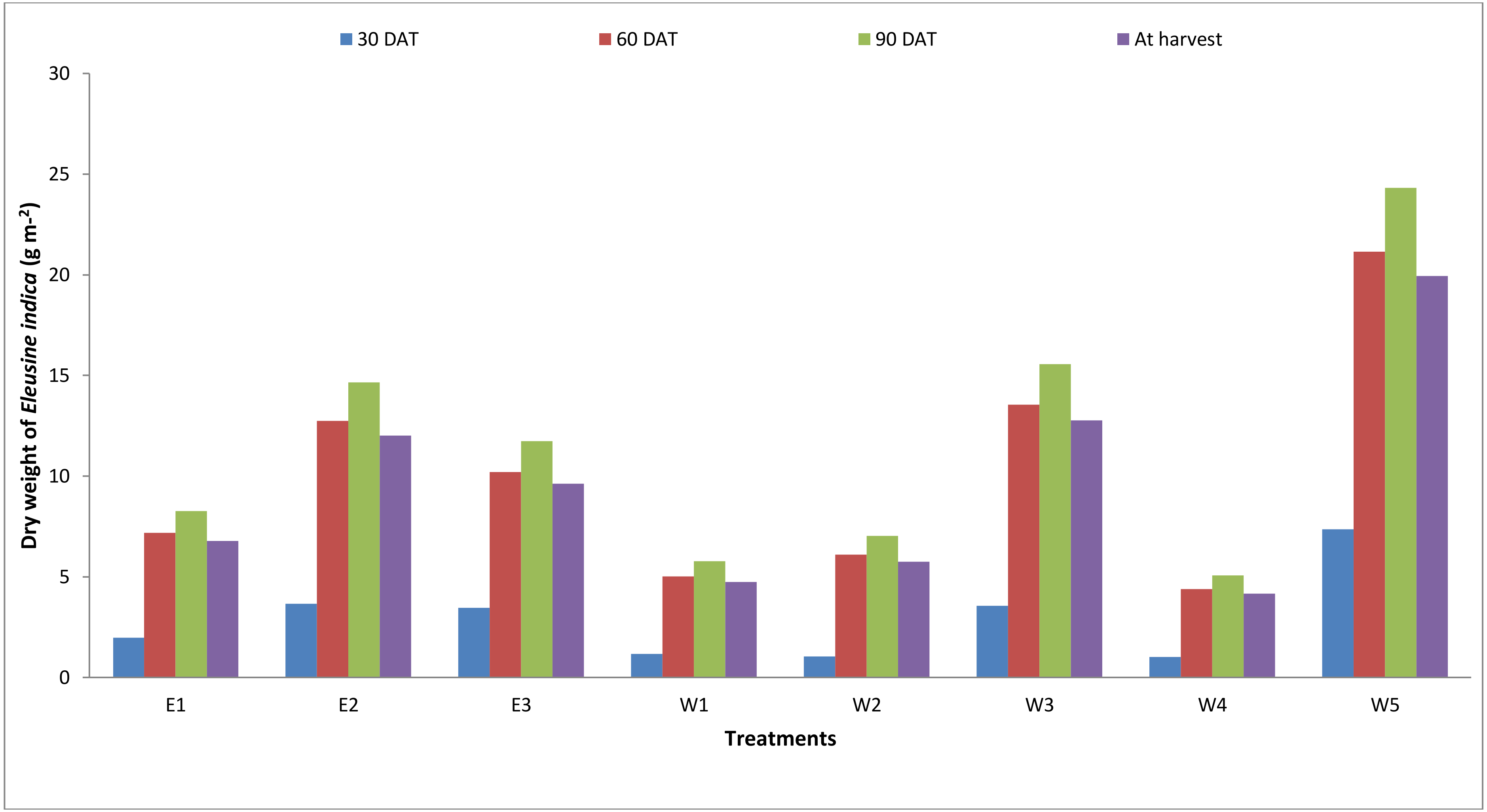


Fig.4.12 (a): Effect of establishment methods and weed management on dry weight of *Eleusine indica* (g m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

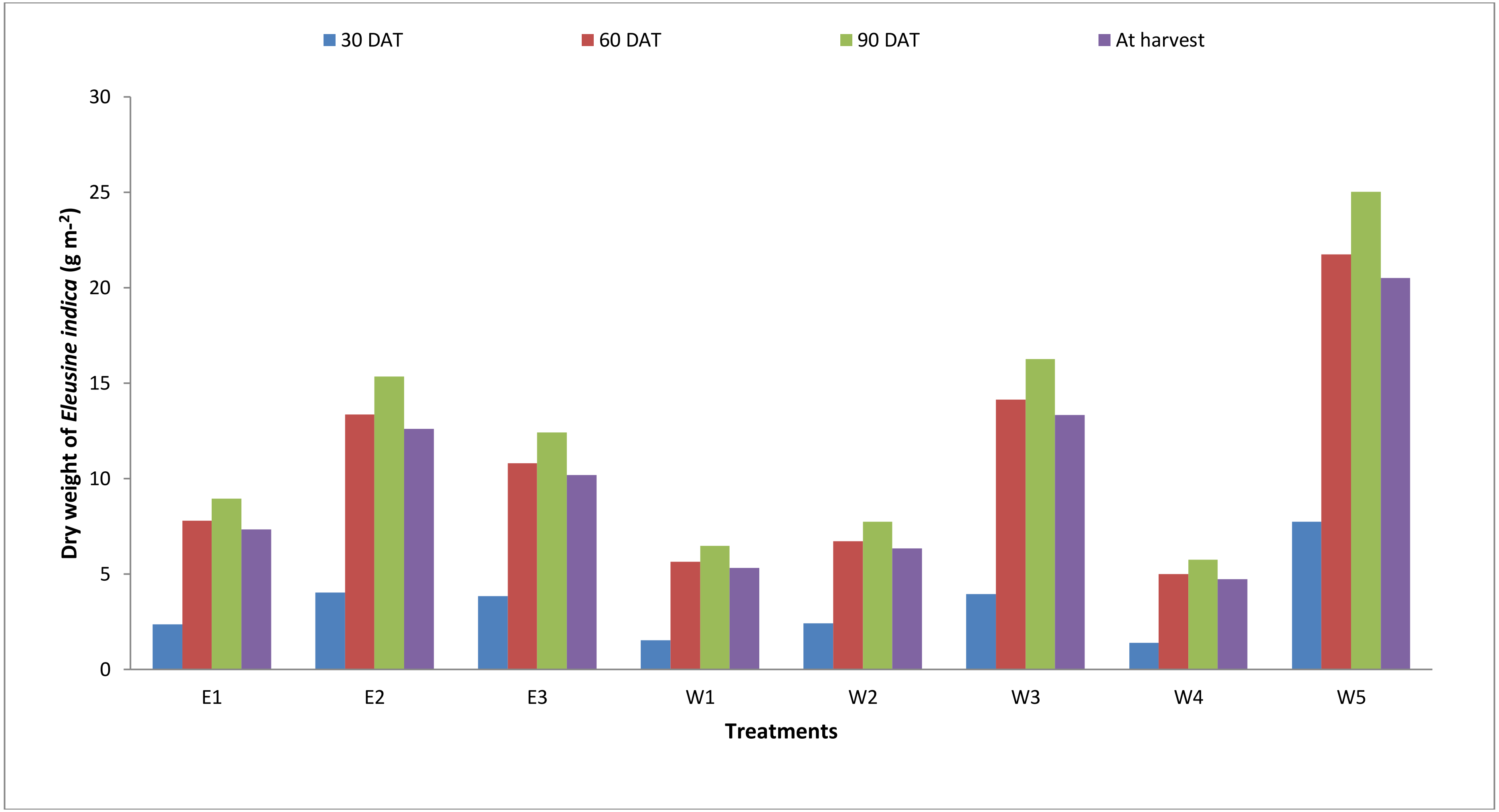


Fig. 4.12 (b): Effect of establishment methods and weed management on dry weight of *Eleusine indica* (g m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

management practices ondry weight of*Eclipta alba* was significant and two hand weedings (W_4) was found most effective in reducingdry weight of*Eclipta alba*as compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing thedry weight of*Eclipta alba*at every observation dates. At harvest, two hand weeding and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) resulted into 56.39, 53.72 and 53.72, 46.04 percent reduction intodry weight of *Eclipta alba*over weedy check (W_5) during 2019 and 2020, respectively.

4.1.2.4*Eleusine indica*dry weight(g m^{-2})

The data regarding the effect of different treatments on dry weight of*Eleusine indica*are presented in Table 4.13, depicted in Fig.4.12, and their analysis of variance is given in appendix XIV. The*Eleusine indica*dry weight increased at 90 DAT and there after decline with the advancement in crop growth.The effect of different crop establishment methods at different observation dates was significant.The minimumdry weight of *Eleusine indica*was recorded under conventionalpuddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum dry weight of *Eleusine indica* was recorded with unpuddled flatmethod (E_2) during both the years.At harvest the percent reduction indry weight of *Eleusine indica* under conventional puddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 14.71, 13.87 and 25.65, 23.93 during 2019 and 2020, respectively.

The weed management practices had significant effect ondry weight of*Eleusine indica* at different days interval of crop growth during both the years. Thedry weight of *Eleusine indica* increased initially and reached maximum at 90 DAT under various weed management practices and there after declined at harvest. The effect of different weed

Table 4.14: Effect of establishment methods and weed management on dry weight of *Phyllanthus niruri*(gm^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Dry wt. of *Phyllanthus niruri* (gm^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	1.49 (2.05)	1.70 (2.66)	2.61 (7.08)	2.70 (7.51)	2.37 (5.80)	2.46 (6.17)	2.17 (4.76)	2.25 (5.06)
E_2-Unpuddled Flat (UPF)	1.77 (2.90)	1.94 (3.51)	3.10 (9.77)	3.17 (10.20)	2.83 (8.09)	2.90 (8.46)	2.58 (6.63)	2.64 (6.93)
E_3-Furrow Irrigated Raised Beds (FIRBs)	1.83 (3.40)	2.01 (4.01)	3.55 (13.13)	3.61 (13.56)	3.25 (10.95)	3.31 (11.31)	2.96 (8.98)	3.01 (9.27)
SE(m)±	***0.03***	***0.03***	***0.06***	***0.06***	***0.06***	***0.06***	***0.05***	***0.05***
C.D(P=0.05)	***0.11***	***0.12***	***0.21***	***0.21***	***0.21***	***0.21***	***0.18***	***0.18***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.30 (1.20)	1.52 (1.81)	2.440 (5.40)	2.49 (5.83)	2.19 (4.38)	2.27 (4.74)	2.00 (3.59)	2.08 (3.89)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.46 (1.69)	1.66 (2.30)	2.65 (6.58)	2.73 (7.01)	2.42 (5.38)	2.49 (5.74)	2.21 (4.41)	2.28 (4.71)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	1.87 (3.02)	2.03 (3.63)	3.59 (12.53)	3.65 (12.96)	3.29 (10.44)	3.35 (10.80)	3.00 (8.56)	3.05 (8.86)
W_4-Two hand weedings	1.06 (0.66)	1.32 (1.27)	2.26 (5.00)	2.36 (5.443)	2.04 (4.04)	2.14 (4.40)	1.88 (3.31)	1.96 (3.61)
W_5-Weedy check	2.78 (7.37)	2.89 (7.98)	4.53 (20.44)	4.58 (20.87)	4.16 (17.17)	4.20 (17.53)	3.77 (14.08)	3.81 (14.38)
SE(m)±	***0.05***	***0.05***	***0.10***	***0.09***	***0.09***	***0.09***	***0.08***	***0.08***
C.D(P=0.05)	***0.15***	***0.15***	***0.30***	***0.29***	***0.27***	***0.27***	***0.25***	***0.25***

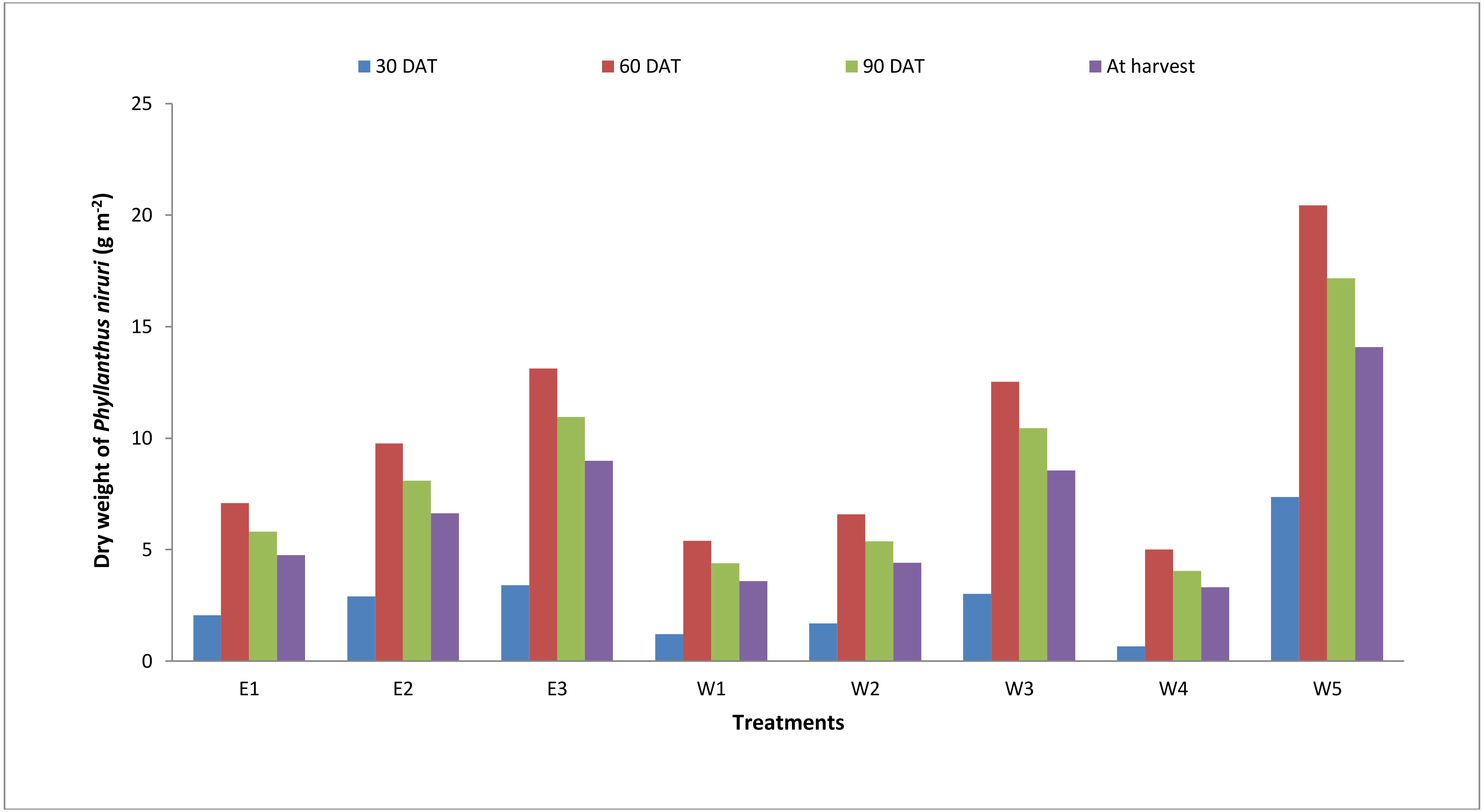


Fig.4.13 (a): Effect of establishment methods and weed management on dry weight of *Phyllanthus niruri* (g m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

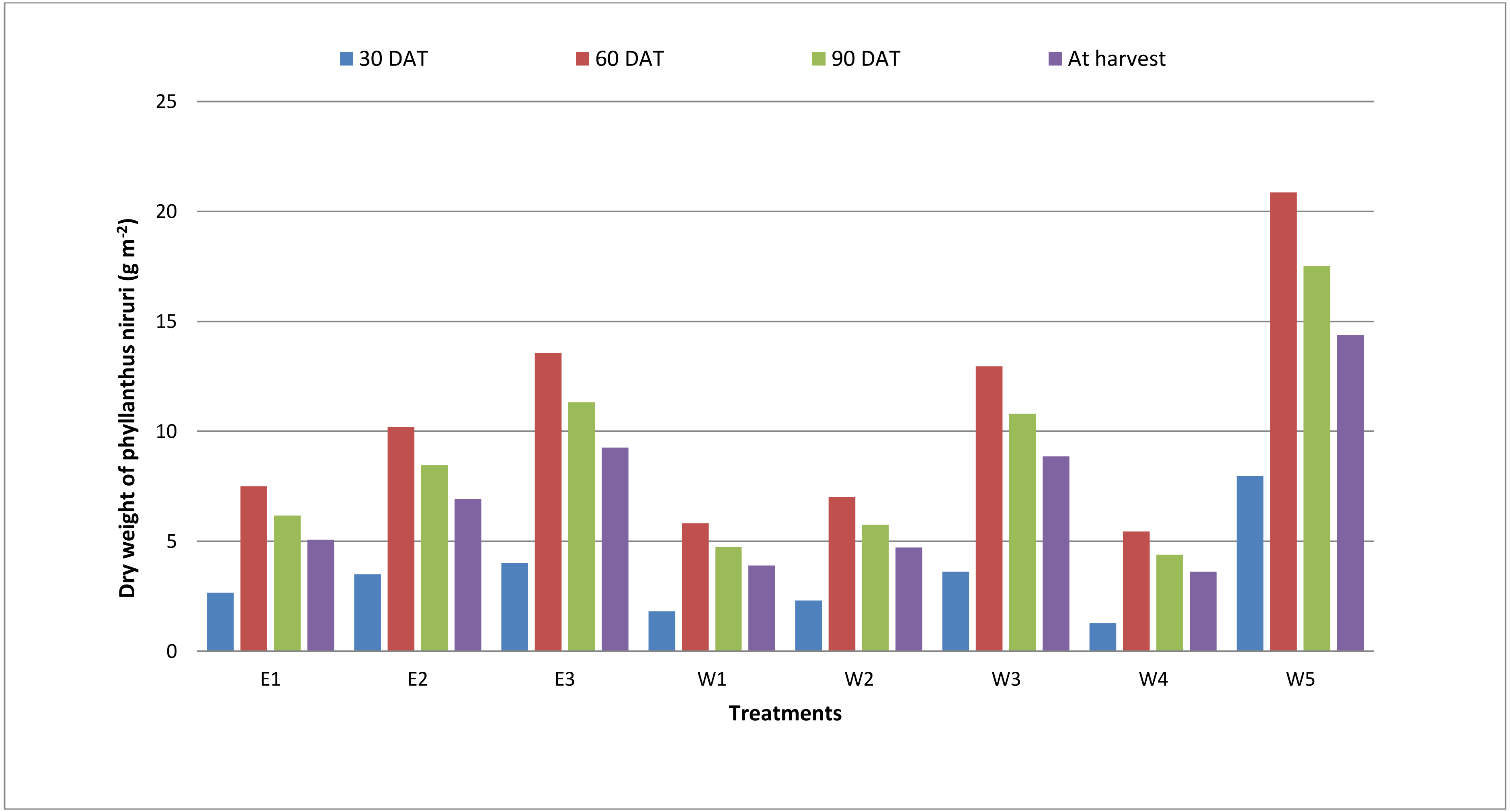


Fig.4.13 (b): Effect of establishment methods and weed management on dry weight of *Phyllanthus niruri* (g m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

management practices ondry weight of *Eleusine indica* was significant and two hand weedings (W_4) was found most effective in reducingdry weight of*Eleusine indica* as compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing thedry weight of*Eleusine indica* at every observation dates. At harvest, two hand weeding (W_4) and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) resulted into 53.00, 50.54 and 49.88, 47.69 percent reduction intodry weight of *Eleusine indica* over weedy check (W_5) during 2019 and 2020, respectively.

4.1.2.5*Phyllanthus niruri* dry weight(g m^{-2})

The data regarding the effect of different treatments on dry weight of*Phyllanthus niruri*are presented in Table 4.14, depicted in Fig.4.13, and their analysis of variance is given in appendix XV. The*Phyllanthus niruri* dry weight increased at 60 DAT and there after decline with the advancement in crop growth.The effect of different crop establishment methods at different observation dates was significant.The minimumdry weight of *Phyllanthus niruri*was recorded under conventionalpuddled transplanting (E_1) followed byunpuddled flatmethod (E_2) while the maximum dry weight of *Phyllanthus niruri* was recorded with furrow irrigated raised bed method (E_3) during both the years.At harvest the percent reduction indry weight of*Phyllanthus niruri* under conventional puddle transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 26.68, 25.24 and 15.89, 14.77 during 2019 and 2020, respectively.

The weed management practices had significant effect ondry weight of*Phyllanthus niruri* at different days interval of crop growth during both the years. Thedry weight of *Phyllanthus niruri* increased initially and reached maximum at 60 DAT

Table 4.15: Effect of establishment methods and weed management on dry weight of other weeds (gm^{-2}) at 30, 60, 90 days after transplanting and at harvest

Treatments	Dry wt. of other weeds (gm^{-2})							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	1.56 (2.19)	1.74 (2.82)	2.97 (10.23)	3.11 (10.89)	2.79 (8.90)	2.91 (9.47)	2.54 (7.30)	2.66 (7.76)
E_2-Unpuddled Flat (UPF)	2.05 (4.40)	2.19 (4.93)	3.97 (16.53)	4.06 (17.19)	3.71 (14.38)	3.79 (14.95)	3.38 (11.79)	3.45 (12.26)
E_3-Furrow Irrigated Raised Beds (FIRBs)	1.69 (2.65)	1.85 (3.18)	3.55 (13.89)	3.65 (14.54)	3.33 (12.16)	3.42 (12.73)	3.03 (9.97)	3.12 (10.44)
SE(m)±	***0.03***	***0.03***	***0.07***	***0.08***	***0.07***	***0.07***	***0.05***	***0.06***
C.D(P=0.05)	***0.10***	***0.11***	***0.27***	***0.27***	***0.24***	***0.24***	***0.21***	***0.20***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.29 (1.20)	1.48 (1.73)	2.61 (6.39)	2.74 (7.04)	2.45 (5.56)	2.57 (6.13)	2.24 (4.56)	2.34 (5.02)
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.46 (1.66)	1.63 (2.19)	2.70 (7.01)	2.82 (7.66)	2.53 (6.09)	2.64 (6.66)	2.31 (5.00)	2.41 (5.46)
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	1.93 (3.24)	2.06 (3.77)	4.44 (19.35)	4.51 (20.00)	4.16 (16.97)	4.23 (17.54)	3.78 (13.91)	3.84 (14.38)
W_4-Two hand weedings	1.19 (0.95)	1.40 (1.48)	2.27 (3.50)	2.43 (6.05)	2.13 (4.69)	2.28 (5.26)	1.96 (3.85)	2.09 (4.32)
W_5-Weedy check	2.96 (8.52)	3.05 (9.05)	5.47 (29.62)	5.53 (30.27)	5.10 (25.76)	5.16 (26.33)	4.63 (21.12)	4.69 (21.59)
SE(m)±	***0.06***	***0.06***	***0.11***	***0.11***	***0.11***	***0.10***	***0.09***	***0.09***
C.D(P=0.05)	***0.17***	***0.18***	***0.35***	***0.33***	***0.33***	***0.31***	***0.28***	***0.27***

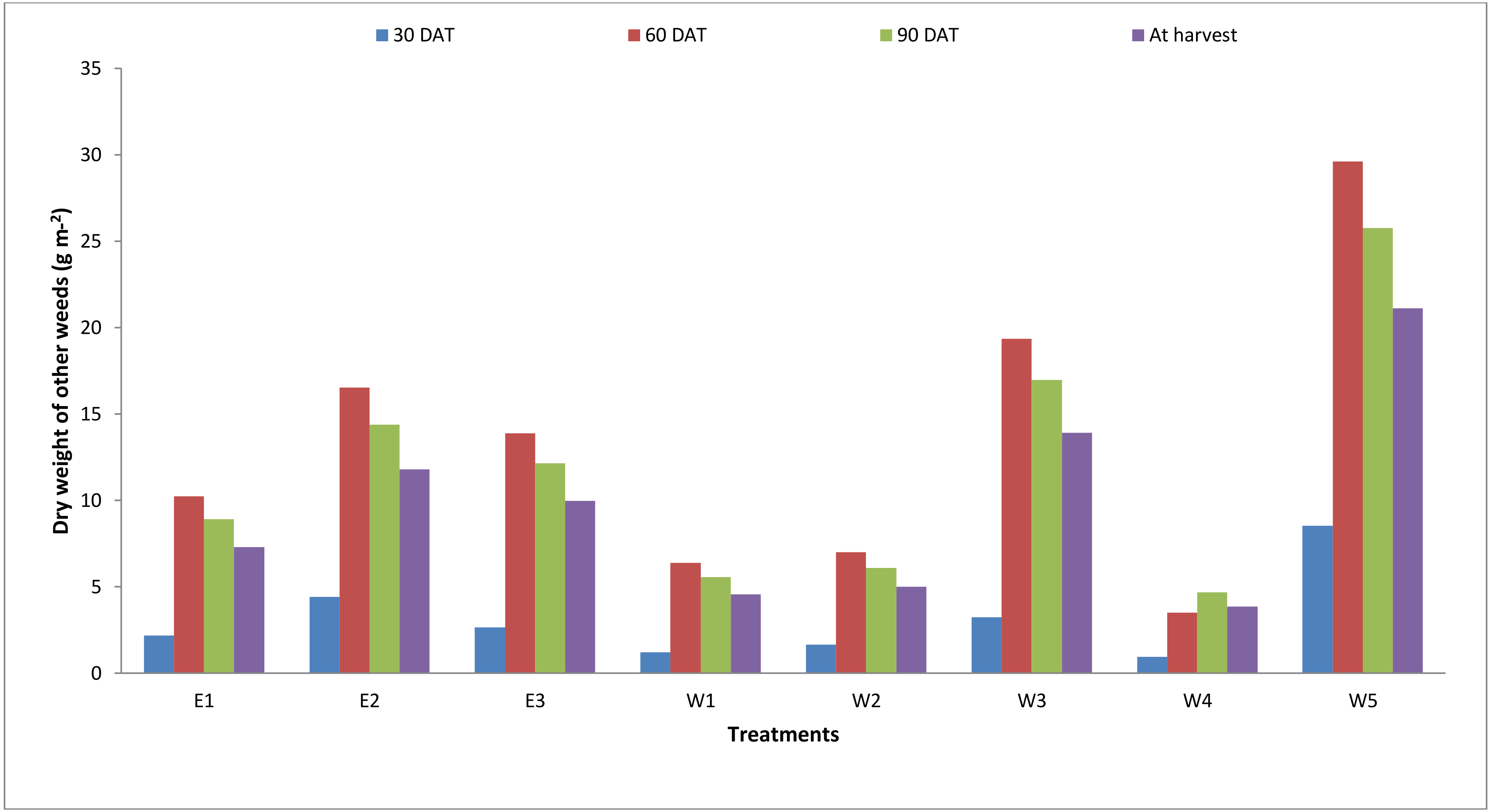


Fig. 4.14 (a): Effect of establishment methods and weed management on dry weight of other weeds (g m^{-2}) at 30, 60, 90 DAT and at harvest (2019)

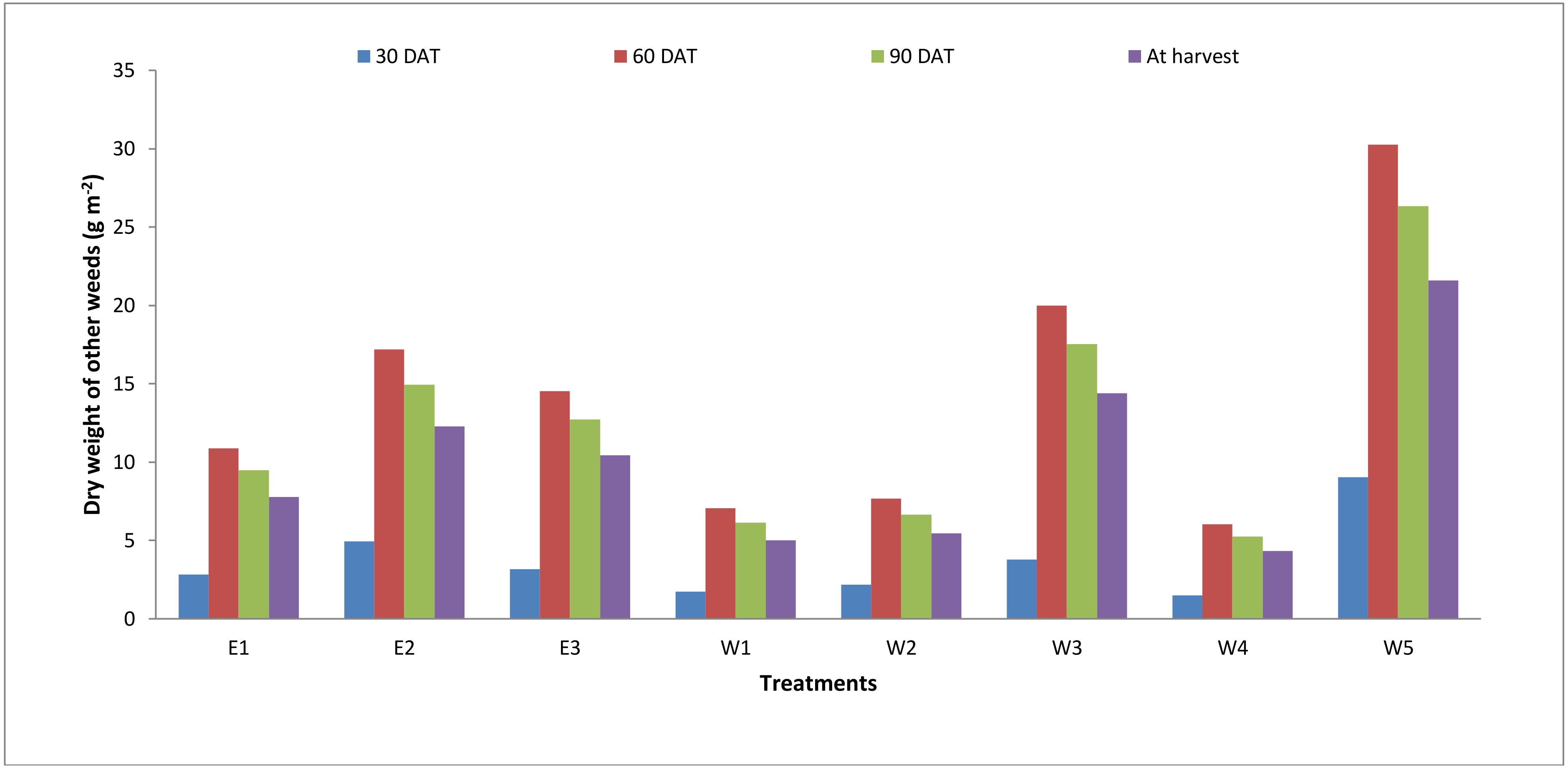


Fig.4.14 (b): Effect of establishment methods and weed management on dry weight of other weeds (g m^{-2}) at 30, 60, 90 DAT and at harvest (2020)

under various weed management practices and there after declined at 90 and at harvest. The effect of different weed management practices ondry weight of*Phyllanthus niruri* was significant and two hand weedings (W_4) was found most effective in reducingdry weight of*Phyllanthus niruri* as compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing thedry weight of*Phyllanthus niruri*at every observation dates. At harvest, two hand weeding (W_4) and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_4) resulted into 50.13, 48.55 and 46.94, 45.40 percent reduction intodry weight of *Phyllanthus niruri* over weedy check (W_5) during 2019 and 2020, respectively.

4.1.2.6Other weeds dry weight(g m^{-2})

The data regarding the effect of different treatments on dry weight ofother weedsare presented in Table 4.15, depicted in Fig.4.14, and their analysis of variance is given in appendix XVI. The other weedsdry weight increased at 60 DAT and there after decline with the advancement in crop growth.The effect of different crop establishment methods at different observation dates was significant.The minimumdry weight of other weedswas recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum dry weight of other weedswas recorded with unpuddled flatmethod (E_2) during both the years.At harvest the percent reduction indry weight of other weeds under conventionalpuddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flatmethod (E_2) was to 16.17, 14.74 and 24.85, 22.89 during 2019 and 2020, respectively.

The weed management practices had significant effect ondry weight ofother weedsat different days interval of crop growth during both the years. Thedry weight of

Table4.16: Effect of weed management practices on weed control efficiency (%) at 60 & 90 Days

Treatments	Weed control efficiency (%)			
	60 DAT	**60 DAT**	**90 DAT**	**90 DAT**
	2019	**2020**	**2019**	**2020**
(E) Crop Establishment Methods				
E_1-Conventional Puddled Transplanting (CPT)	61.34	57.74	59.42	57.80
E_2-Unpuddled Flat (UPF)	51.99	48.40	49.22	48.15
E_3-Furrow Irrigated Raised Beds (FIRBs)	56.66	52.55	53.25	52.14
SE(m)±	***1.41***	***1.03***	***2.00***	***1.95***
C.D (P=0.05)	***4.99***	***3.66***	***7.06***	***6.90***
(W) Weed Management Options				
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	80.36	75.67	77.16	75.36
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	77.04	71.99	73.37	71.65
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	42.09	38.06	39.07	38.16
W_4-Two hand weedings	83.83	78.75	80.22	78.33
W_5-Weedy check	0.00	0.00	0.00	0.00
SE(m)±	***1.52***	***1.17***	***2.01***	***1.97***
C.D (P=0.05)	***4.37***	***3.37***	***5.81***	***5.67***

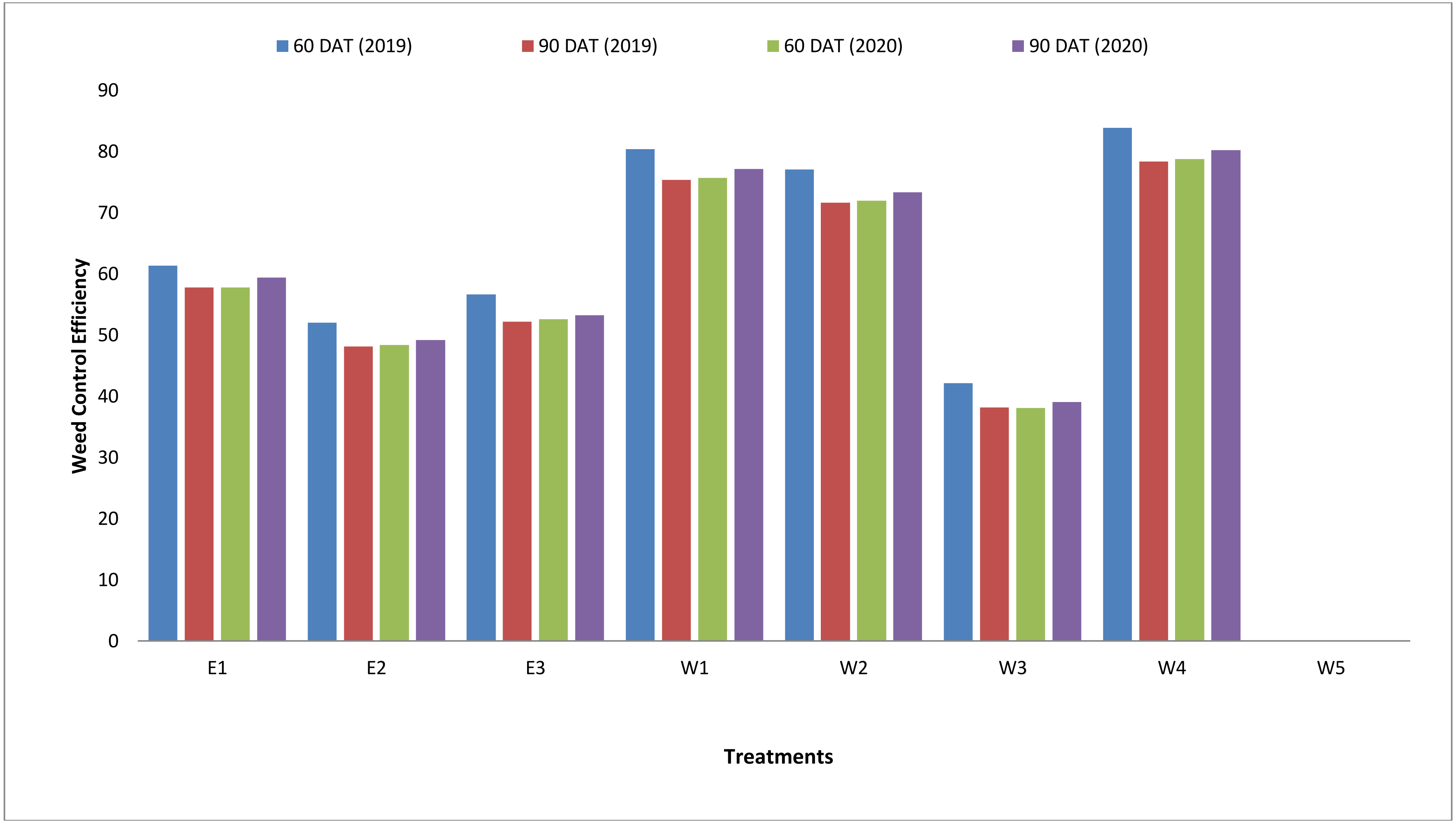


Fig. 4.15: Effect of Establishment methods and Weed management practices on weed control efficiency of basmati rice (2019- 2020)

other weedsincreased initially and reached maximum at 60 DAT under various weed management practices and there after declined at 90 and at harvest. The effect of different weed management practices ondry weight ofother weedswas significant and two hand weedings (W_4) was found most effective in reducingdry weight ofother weedsas compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) was found most effective in reducing thedry weight ofother weedsat every observation dates. At harvest, two hand weeding and Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) resulted into 57.66, 55.43 and 51.61, 50.10 percent reduction intodry weight of other weedsover weedy check (W_5) during 2019 and 2020, respectively.

4.1.2.7 Weed control efficiency (WCE %) at 60 and 90 days)

The data regarding the effect of different treatments on weed control efficiency (%) are presented in Table 4.16, depicted in Fig. 4.15, and their analysis of variance is given in appendix XVII. Weed control efficiency (%) to suppress weed growth, varied with crop establishment methods and weed management practices. In crop establishment methods, the maximum weed control efficiencyat 60 and 90 days was found (61.34, 57.74 and 59.42, 57.80 %) under conventionalpuddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while theminimum weed control efficiency was found (56.66, 52.55 and 53.25, 52.14 %) with unpuddled flatmethod (E_2) during 2019 and 2020, respectively.

Among the weed management practices, the maximum weed control efficiency at 60 and 90 days was found (83.83, 78.75 and 80.22, 78.33 %) with two hand weedings (W_4) followed byPretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}

Table 4.17: Effect of establishment methods and weed managementon plant height (cm) at different stages of Basmati rice.

Treatments	Plant height (cm)							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	44.3	46.3	70.9	72.9	97.2	99.7	96.3	99.2
E_2-Unpuddled Flat (UPF)	40.2	40.8	63.3	63.9	88.1	90.1	88.1	90.0
E_3-Furrow Irrigated Raised Beds (FIRBs)	42.4	44.4	67.8	69.8	92.5	93.9	92.8	93.8
SE(m)±	***0.82***	***0.86***	***1.34***	***1.28***	***1.75***	***2.14***	***1.83***	***1.87***
C.D(P=0.05)	***2.85***	***3.00***	***4.65***	***4.44***	***6.05***	***7.43***	***6.34***	***6.48***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	45.5	46.5	72.3	74.0	99.0	100.7	98.8	100.6
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	43.9	45.5	71.4	73.0	97.5	99.4	96.9	99.3
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	40.8	42.5	68.4	70.1	94.4	96.8	94.3	96.9
W_4-Two hand weedings	42.3	44.0	70.7	72.4	96.9	98.6	96.8	98.2
W_5-Weedy check	39.1	40.8	54.0	55.0	75.2	77.5	75.2	76.8
SE(m)±	***0.83***	***0.89***	***1.28***	***1.31***	***1.76***	***1.89***	***1.76***	***1.81***
C.D(P=0.05)	***2.48***	***2.67***	***3.80***	***3.90***	***5.23***	***5.63***	***5.24***	***5.40***

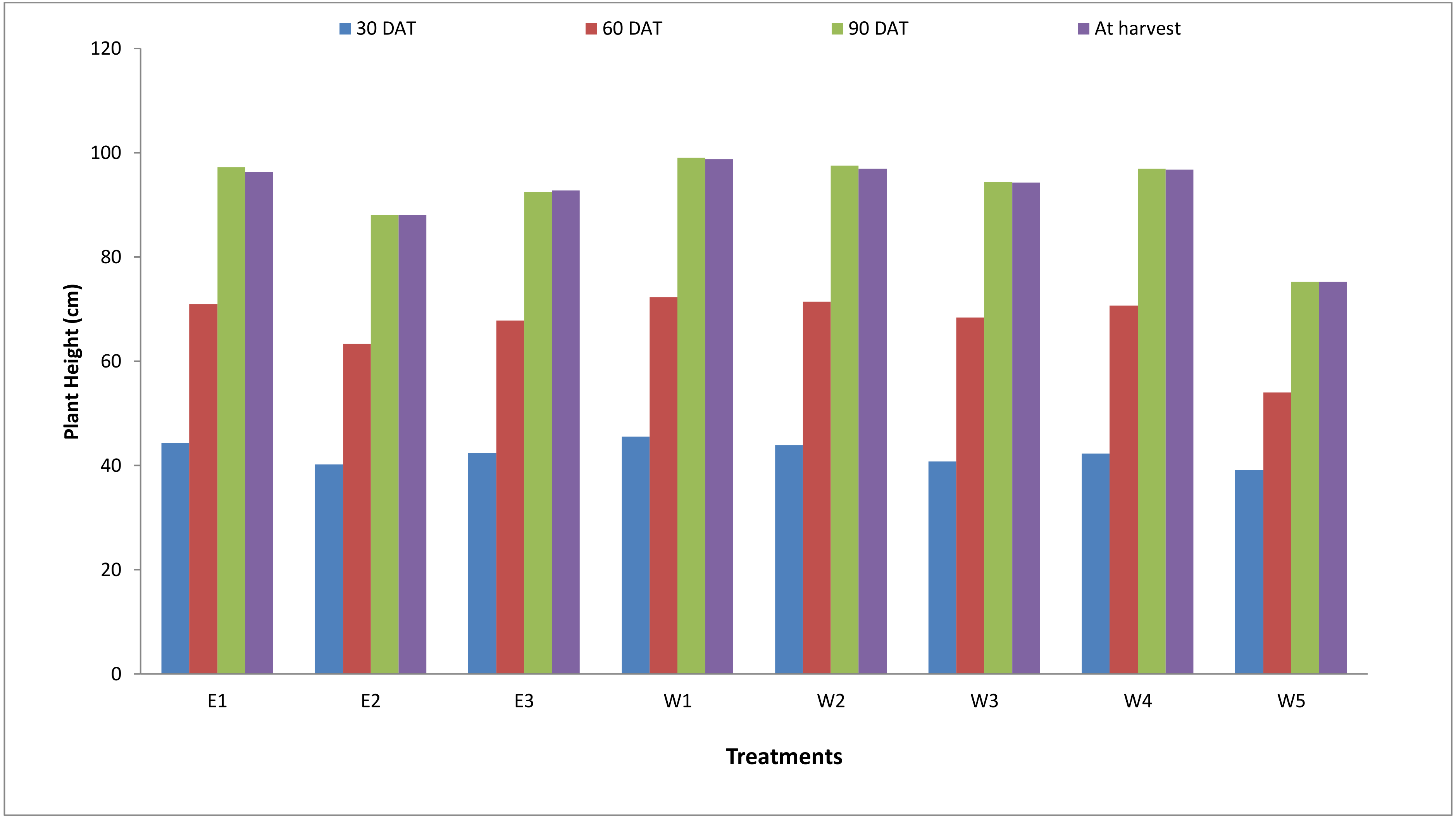


Fig. 4.16 (a): Effect of establishment methods and weed management on plant height (cm) at different stages of Basmati rice (2019)

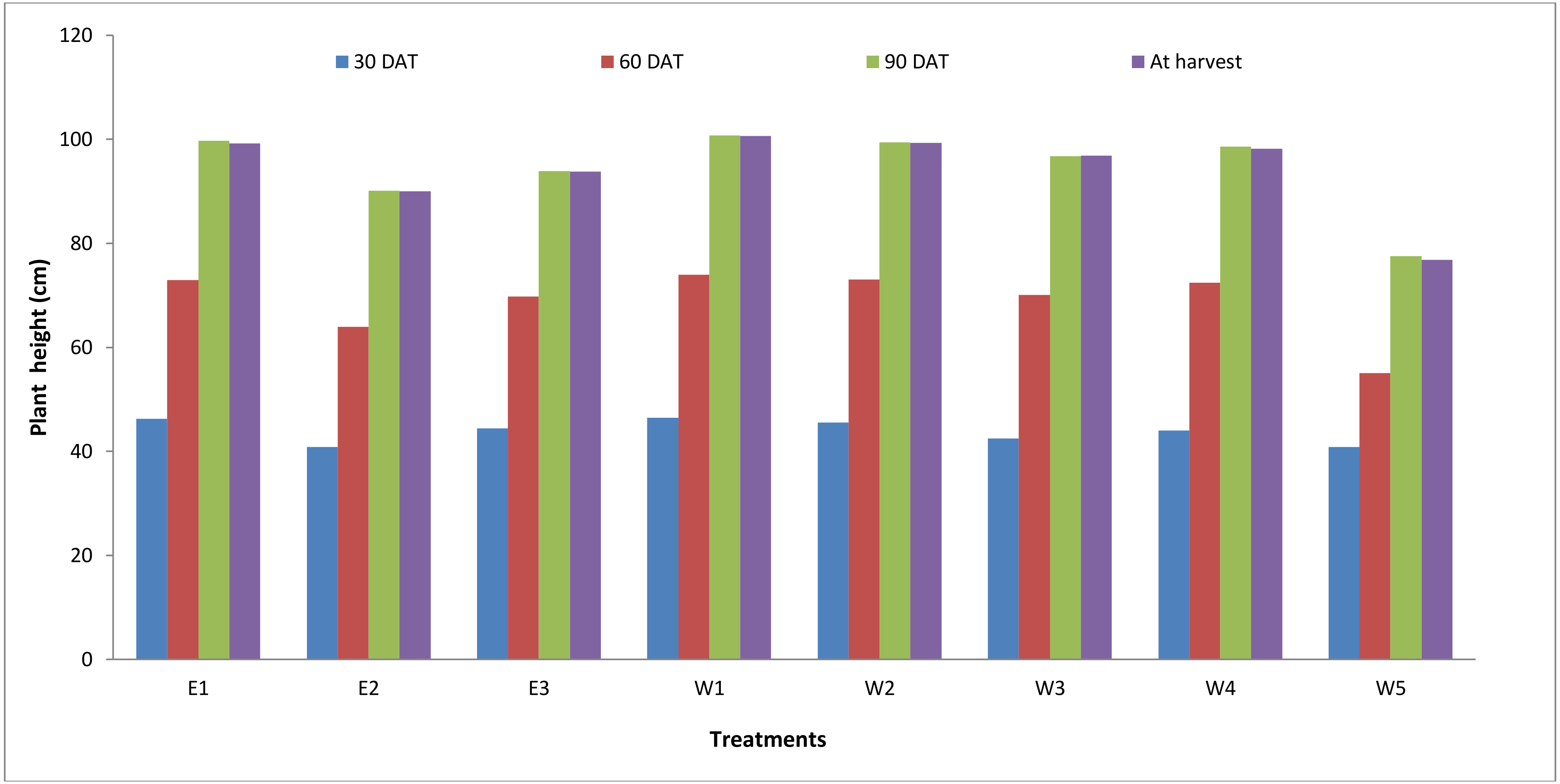


Fig. 4.16 (b): Effect of establishment methods and weed management on plant height (cm) at different stages of Basmati rice (2020)

(W_1) while the lowest weed control efficiency was found (42.09, 38.06 and 39.07, 38.16 %) with Bispyribac sodium @ 25 g a.i. ha^{-1} (W_3) during both the years,respectively.

4.2 Studies of crop

4.2.1 Plant height (cm)

Plant height tended to increase with advancement in crop age, irrespective of thecrop establishment methods and weed management practices. The data regarding the effect of different treatments on plant height are presented in Table 4.17, depicted in Fig. 4.16, and their analysis of variance is given in appendix XVIII. The rate of growth was higher during 30 to 90 days period than at harvest.

The effect of different crop establishment methods onplant height at different observation dates was significant.The maximum plant height was recorded under conventionalpuddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the minimumplant height was recorded under unpuddled flat (E_2)method during both the years.

The weed management practices had significant effect onplant height at different days interval of crop growth during both the years. Theplant height was increased initially and reached maximum at 90 DAT under various weed management practices and there after declined at harvest. The effect of different weed management practices onplant heightwas significant and the maximum plant height was recorded with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1)which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) followed by two hand weedings (W_4) and Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3)$^{.}$ The minimum plant height was recorded with weedy check (W_5) at all the stages during both

Table 4.18: Effect of establishment methods and weed managementon number of tillers (m^{-2}) at different stages of Basmati rice

Treatments	Number of tillers							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	125.4	127.4	230.9	236.6	220.4	223.7	218.4	220.8
E_2-Unpuddled Flat (UPF)	121.5	122.5	220.1	221.3	208.9	211.9	204.8	208.1
E_3-Furrow Irrigated Raised Beds (FIRBs)	132.9	134.7	240.4	243.8	228.7	231.7	225.0	227.6
SE(m)±	***2.53***	***2.44***	***4.43***	***4.56***	***4.25***	***4.50***	***4.36***	***4.20***
C.D(P=0.05)	***8.77***	***8.45***	***15.33***	***15.80***	***14.73***	***15.59***	***15.12***	***14.54***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	135.3	136.6	255.4	257.4	243.0	245.0	239.7	241.4
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	133.7	135.3	250.6	255.3	238.9	243.6	235.6	239.9
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	131.8	133.8	233.9	236.9	222.5	224.9	219.5	220.9
W_4-Two hand weedings	123.7	125.7	249.0	254.3	237.3	243.0	234.7	239.3
W_5-Weedy check	108.3	109.3	163.5	165.7	155.0	155.7	151.04	152.7
SE(m)±	***2.48***	***2.49***	***4.55***	***4.56***	***4.33***	***4.46***	***4.31***	***4.41***
C.D(P=0.05)	***7.39***	***7.41***	***13.54***	***13.55***	***12.89***	***13.26***	***12.81***	***13.11***

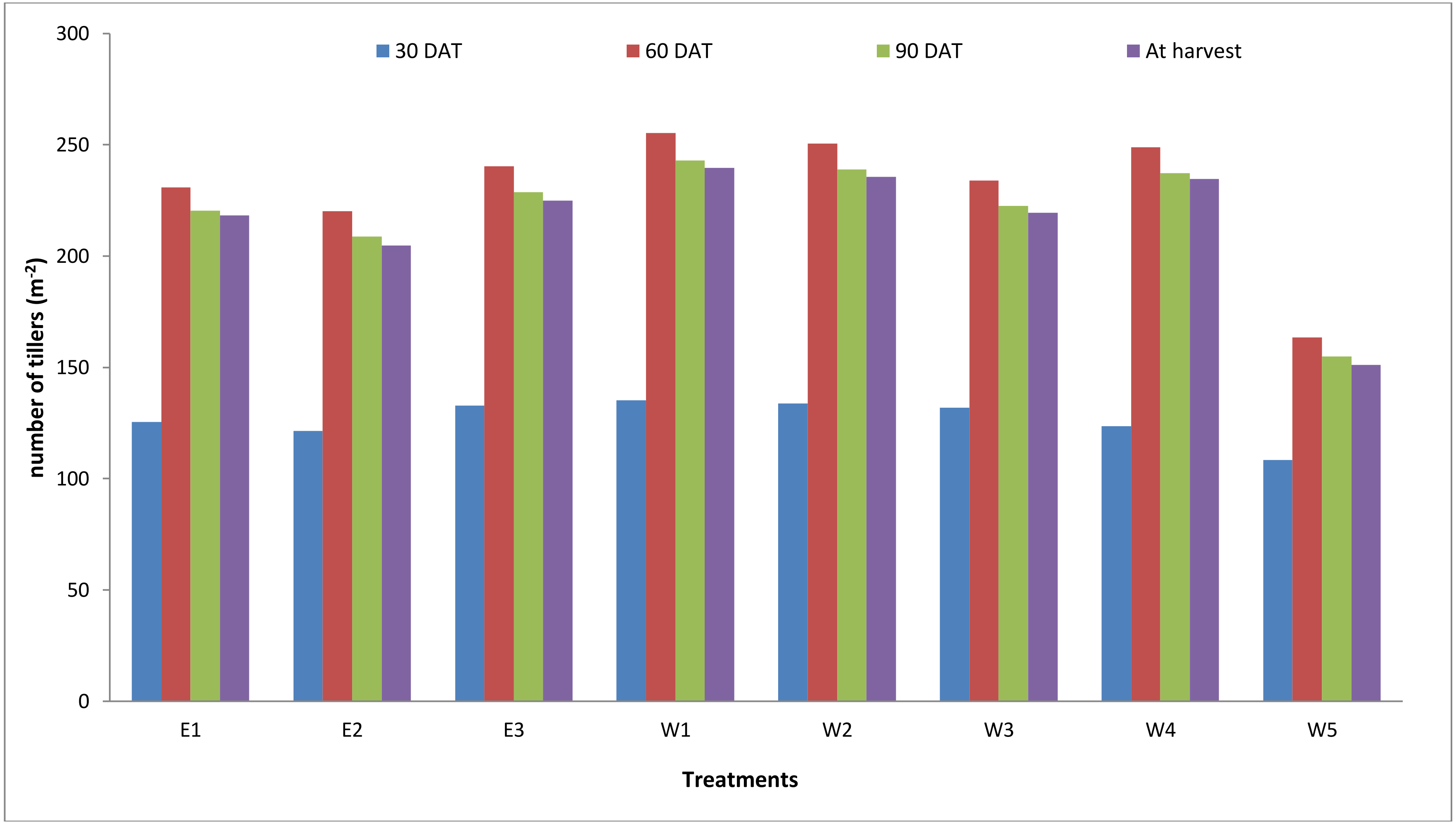


Fig.4.17 (a): Effect of establishment methods and weed management on number of tillers (m^{-2}) at different stages of Basmati rice (2019)

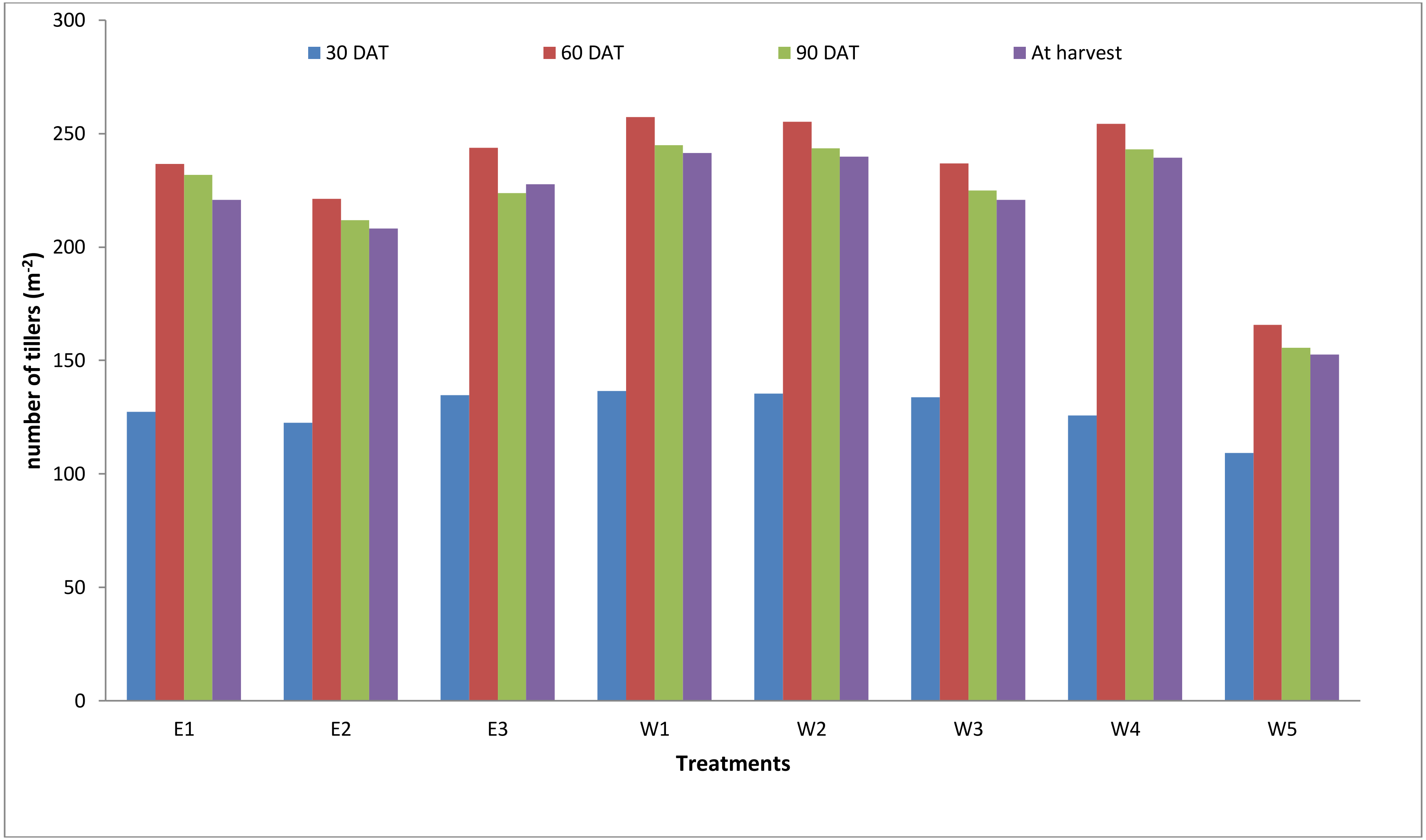


Fig.4.17 (b): Effect of establishment methods and weed management on number of tillers (m^{-2}) at different stages of Basmati rice (2020)

the years.Theplant height had no any significant interaction effect between crop establishment methods and weed management practices.

4.2.2 Number of tillers (m^{-2})

Number of tillers differed significantly under the influence of crop establishment methods and weed management practices at all the crop growth stages in rice. The data regarding the effect of different treatments on number of tillers are presented in Table 4.18, depicted in Fig. 4.17 and their analysis of variance is given in appendix XIX.Number of tillers tended to increase with advancement in crop age upto 60 days and then stared declining at 90 and at harvest. The effect of different crop establishment methods on number of tillers at different observation dates was significant. The maximum number of tillers was recorded under furrow irrigated raised bed method (E_3) which was at par withconventional puddled transplanting (E_1) while the minimumnumber of tillers was recorded under unpuddled flatmethod (E_2) during both the years.

The weed management practices had significant effect onnumber of tillersat different days interval of crop growth during both the years. Thenumber of tillers was increased initially and reached maximum at 60 DAT under various weed management practices and there after declined at 90 DAT and at harvest. The effect of different weed management practices onnumber of tillerswas significant and the maximum number of tillerswas recorded with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) and two hand weedings (W_4) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) at all the stages. The minimum number of tillerswas recorded with weedy check (W_5) at all the stages during both the years.There was no any significant

Table 4.19: Effect of establishment methods and weed managementon dry matter accumulation (g m^{-2}) at different stages of Basmati rice

Treatments	Dry matter accumulation							
	30 DAT		60 DAT		90 DAT		At harvest	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	150.57	155.77	685.12	703.12	1062.64	1084.64	1091.39	1109.39
E_2-Unpuddled Flat (UPF)	133.83	137.17	601.07	613.07	913.98	939.98	921.62	957.62
E_3-Furrow Irrigated Raised Beds (FIRBs)	142.34	145.74	622.54	652.54	1000.26	1026.26	1051.57	1049.57
SE(m)±	***2.50***	***2.11***	***9.13***	***9.21***	***14.01***	***13.99***	***13.92***	***14.76***
C.D(P=0.05)	***8.66***	***7.30***	***31.61***	***31.89***	***48.49***	***48.42***	***48.32***	***51.10***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	151.46	154.96	662.81	684.81	1079.38	1098.71	1119.53	1122.20
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	149.62	153.47	655.01	677.01	1055.76	1081.76	1103.77	1109.77
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	140.87	145.49	618.76	637.43	974.71	1000.71	997.88	1023.88
W_4-Two hand weedings	148.38	152.21	651.22	669.89	1036.07	1062.07	1059.52	1085.52
W_5-Weedy check	120.89	124.98	593.42	612.08	815.55	841.55	826.93	852.93
SE(m)±	***2.96***	***2.69***	***11.49***	***11.81***	***17.15***	***17.79***	***17.19***	***18.62***
C.D(P=0.05)	***8.81***	***8.00***	***34.16***	***35.10***	***50.97***	***52.87***	***51.09***	***55.34***

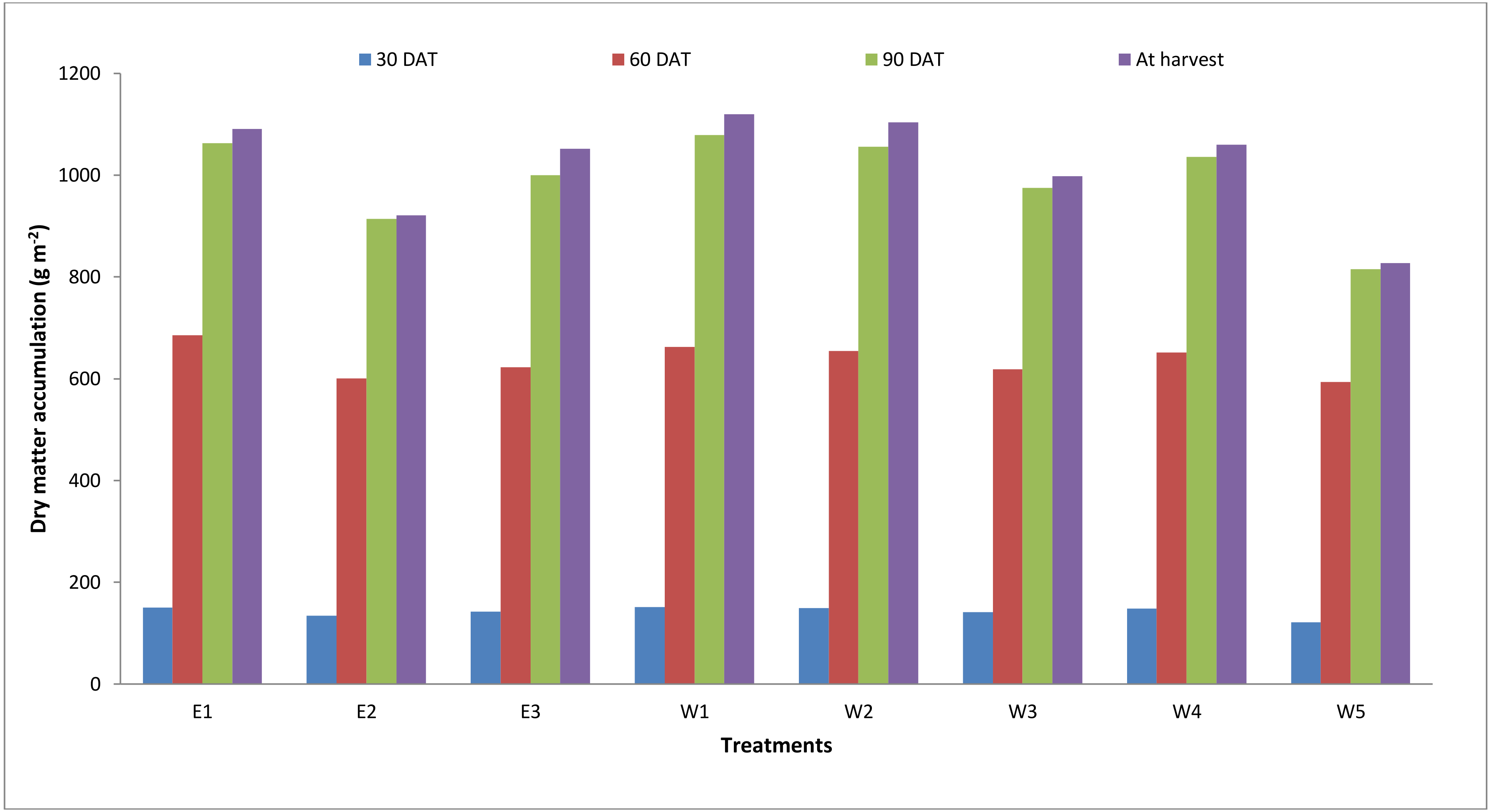


Fig. 4.18(a): Effect of establishment methods and weed management on dry matter accumulation (g m^{-2}) at different stages of Basmati rice (2019)

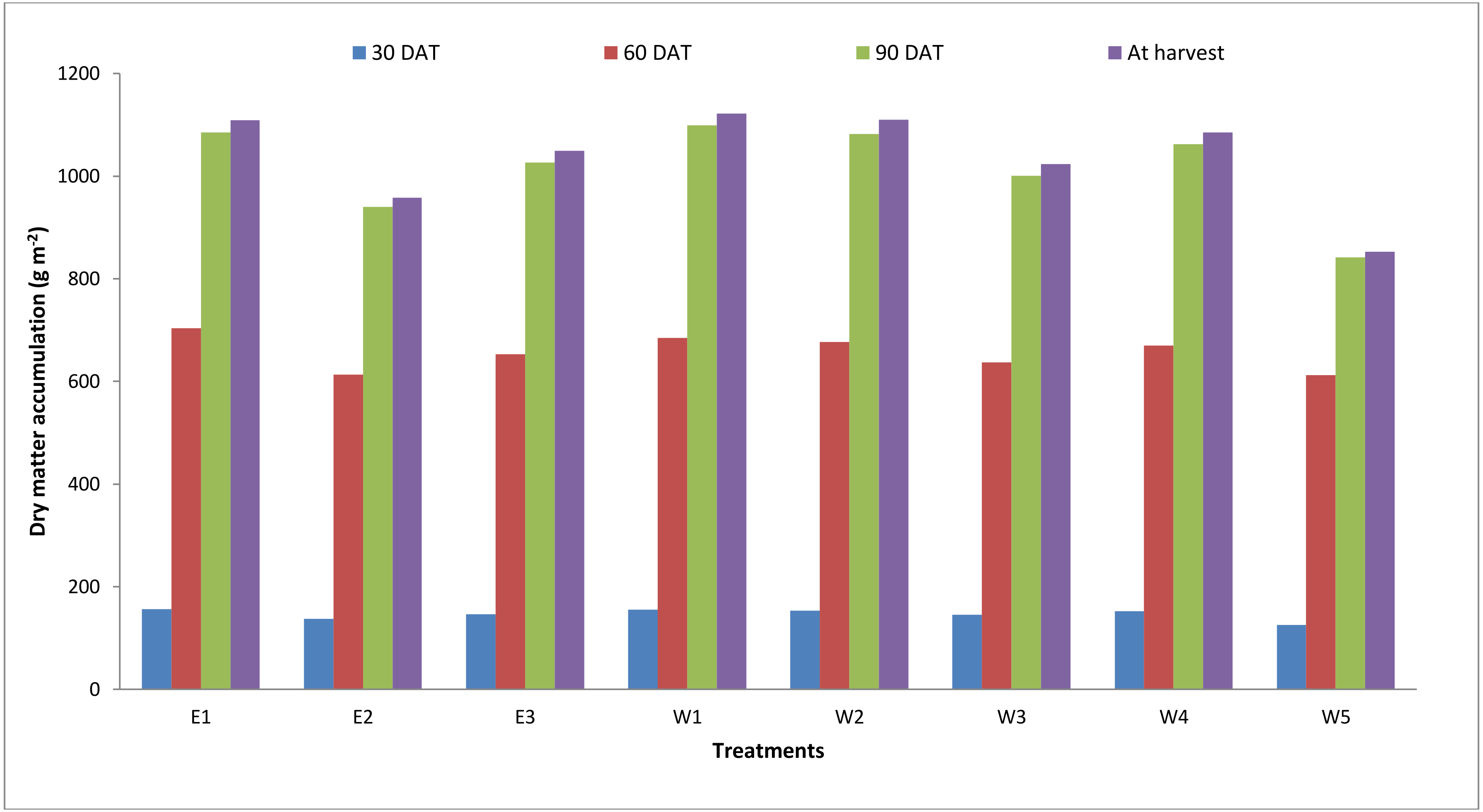


Fig.4.18 (b): Effect of establishment methods and weed management on dry matter accumulation (g m^{-2}) at different stages of Basmati rice (2020)

interaction between crop establishment methods and weed management practices onnumber of tillers.

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

The dry matter accumulation (g m^{-2}) in rice increased with advancement in crop age and reached to a maximum at maturity. The rate of increase was however, slow up to 30 days and reached its peak between 60 days to harvesting.The data regarding the effect of different treatments on dry matter accumulation are presented in Table 4.19, depicted in Fig. 4.18, and their analysis of variance is given in appendix XX.The effect of different crop establishment methods on dry matter accumulationat different observation dates was significant. The maximum dry matter accumulationwas recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the minimumdry matter accumulationwas recorded under unpuddled flat(E_2) method during both the years.

The weed management practices had significant effect ondry matter accumulationat different days interval of crop growth during both the years. Among weed control treatments the minimum dry matter at 30, 60, 90 DAT and harvest found in weedy check which was significantly lower than the remaining treatments. The maximumdry matter was recorded with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) and two hand weedings (W_4) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) at all the stages during both the years.There was no any significant interaction between crop establishment methods and weed management practices ondry matter accumulation.

Table 4.20: Effect of establishment methods and weed managementon leaf area index at different stages of Basmati rice

Treatments	Leaf area index					
	30 DAT		60 DAT		90 DAT	
	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods						
E_1-Conventional Puddled Transplanting (CPT)	2.47	2.51	5.70	5.87	4.80	5.00
E_2-Unpuddled Flat (UPF)	2.30	2.35	5.33	5.35	4.46	4.59
E_3-Furrow Irrigated Raised Beds (FIRBs)	2.37	2.40	5.62	5.69	4.77	4.92
SE(m)±	***0.03***	***0.03***	***0.07***	***0.08***	***0.06***	***0.10***
C.D(P=0.05)	***0.11***	***0.12***	***0.27***	***0.28***	***0.23***	***0.35***
(W) Weed Management Options						
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.48	2.52	6.12	6.32	5.25	5.41
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.46	2.50	6.09	6.15	5.22	5.36
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	2.37	2.41	5.27	5.34	4.38	4.62
W_4-Two hand weedings	2.45	2.49	6.08	6.12	5.21	5.34
W_5-Weedy check	2.14	2.18	4.21	4.25	3.33	3.45
SE(m)±	***0.05***	***0.05***	***0.18***	***0.20***	***0.18***	***0.22***
C.D(P=0.05)	***0.16***	***0.17***	***0.55***	***0.60***	***0.54***	***0.66***

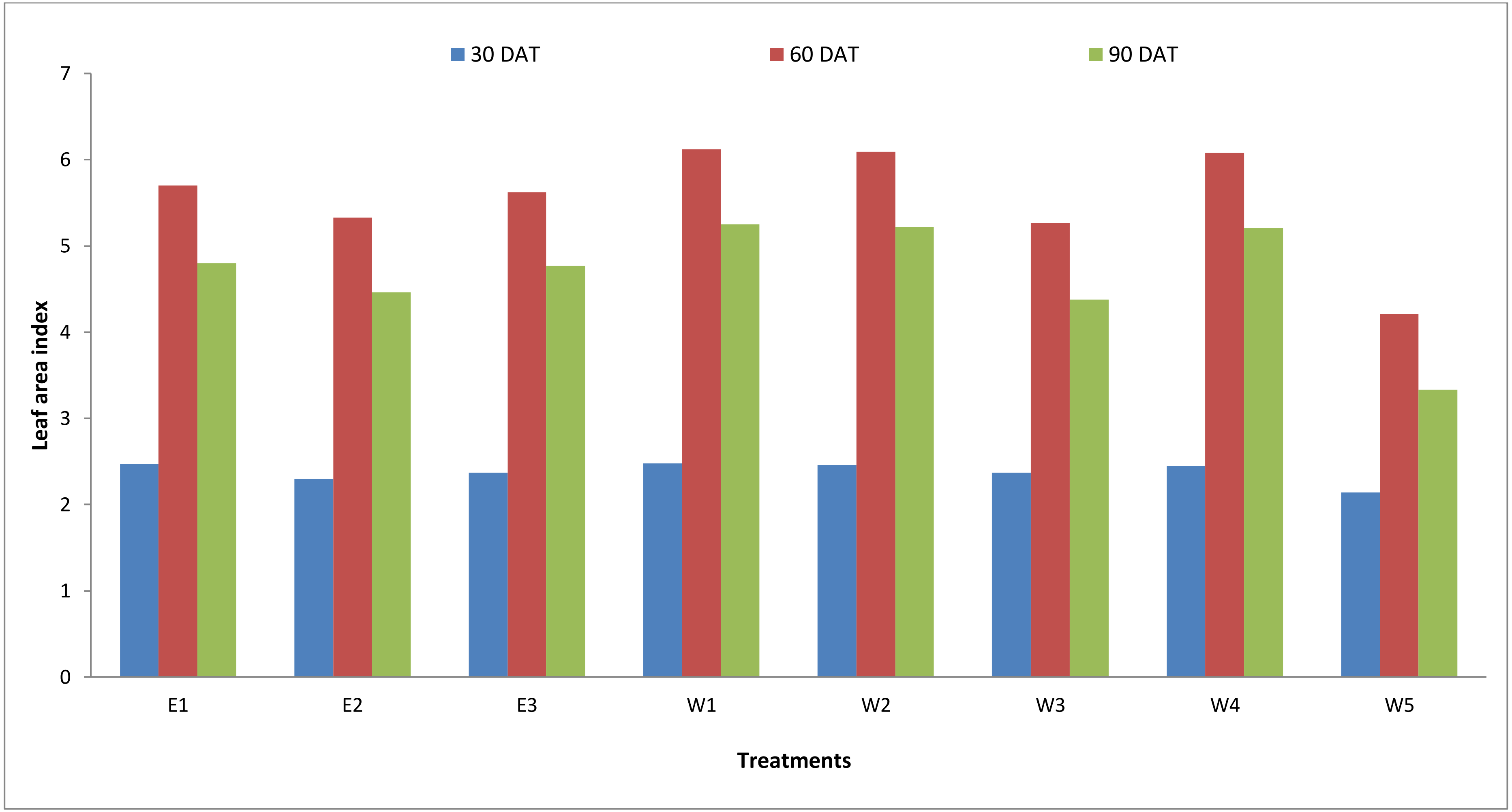


Fig. 4.19(a): Effect of establishment methods and weed management on leaf area index at different stages of Basmati rice (2019)

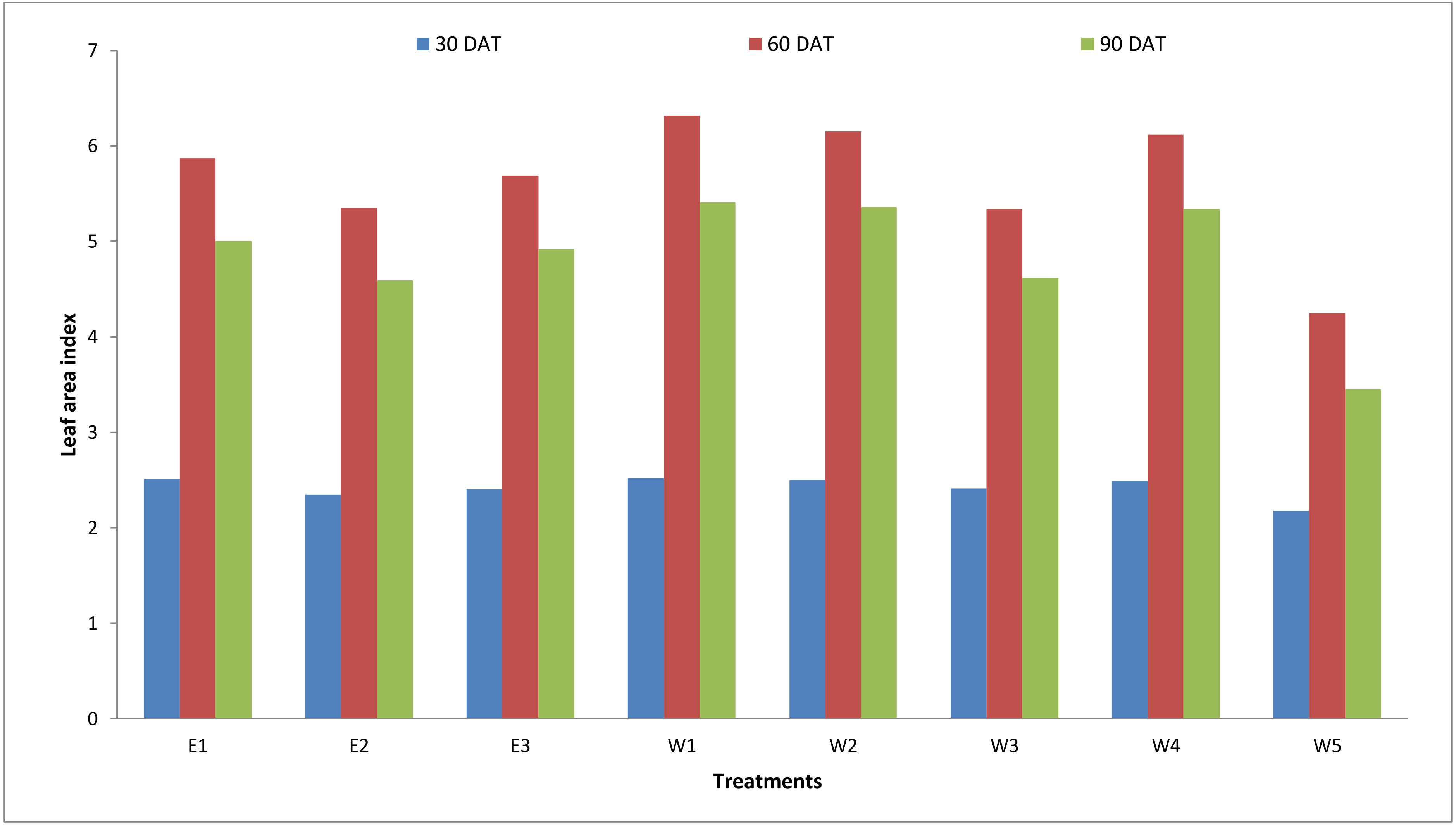


Fig. 4.19(b): Effect of establishment methods and weed management on leaf area index at different stages of Basmati rice (2020)

4.2.4 Leaf Area Index (LAI)

The data pertaining to LAI in rice crop at 30, 60 and 90 DAT is presented in Table 4.20 and depicted in Fig. 4.19 and their analysis of variance is given in appendix XXI.Themaximumleaf area index was recorded at 60 DAT than declined at 90 DAT.

The effect of different crop establishment methods onLAIat different observation dates was significant.

The weed management practices had significant effect onLAI at different days interval of crop growth during both the years. Among weed control treatments the minimumLAI at 30, 60 and 90 DAT found in weedy check which was significantly lower than the remaining treatments. The maximumLAI was recorded with Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} (W_2) and two hand weedings (W_4) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) at 60 and 90 DAT during both the years.There was no any significant interaction between crop establishment methods and weed management practices on LAI.

4.2.5Crop Growth Rate (g/m^2/day)

The data pertaining tocrop growth ratein rice crop at 30-60 and 60-90 DAT is presented in Table 4.21 and Fig. 4.20 and their analysis of variance is given in appendix XXII.Crop growth rate was influenced significantly bycrop establishment methods and weed management practices. The highest CGR values were recorded during 30-60 DAT, whereas lowest during 60-90 DAT.The effect of different crop establishment methods onCGR at different observation dates was significant.The maximumCGR (17.82, 18.25 and 12.58, 12.68g/m^2/day) was recorded under conventional puddled transplanting(E_1) followed by furrow irrigated raised bed method (E_3) (16.01,16.89 and 12.26, 12.48g/m^2/day) while the minimumCGR (15.73,15.86 and 9.76, 11.61

Table 4.21: Effect of establishment methods and weed managementon Crop Growth Rate (g/m^2/day)

Treatments	Crop Growth Rate			
	30-60 DAT		60-90 DAT	
	2019	2020	2019	2020
(E) Crop Establishment Methods				
E_1-Conventional Puddled Transplanting (CPT)	17.82	18.25	12.58	12.72
E_2-Unpuddled Flat (UPF)	15.73	15.86	10.43	10.90
E_3-Furrow Irrigated Raised Beds (FIRBs)	16.01	16.89	12.59	12.46
SE(m)±	***0.30***	***0.31***	***0.24***	***0.26***
C.D(P=0.05)	***1.06***	***1.08***	***0.85***	***0.91***
(W) Weed Management Options				
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	17.09	17.66	13.89	13.80
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	16.88	17.45	13.36	13.49
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	15.96	16.40	11.87	12.11
W_4-Two hand weedings	16.87	17.26	12.83	13.07
W_5-Weedy check	15.78	16.24	7.40	7.65
SE(m)±	***0.36***	***0.37***	***0.32***	***0.36***
C.D(P=0.05)	***1.09***	***1.10***	***0.96***	***1.08***

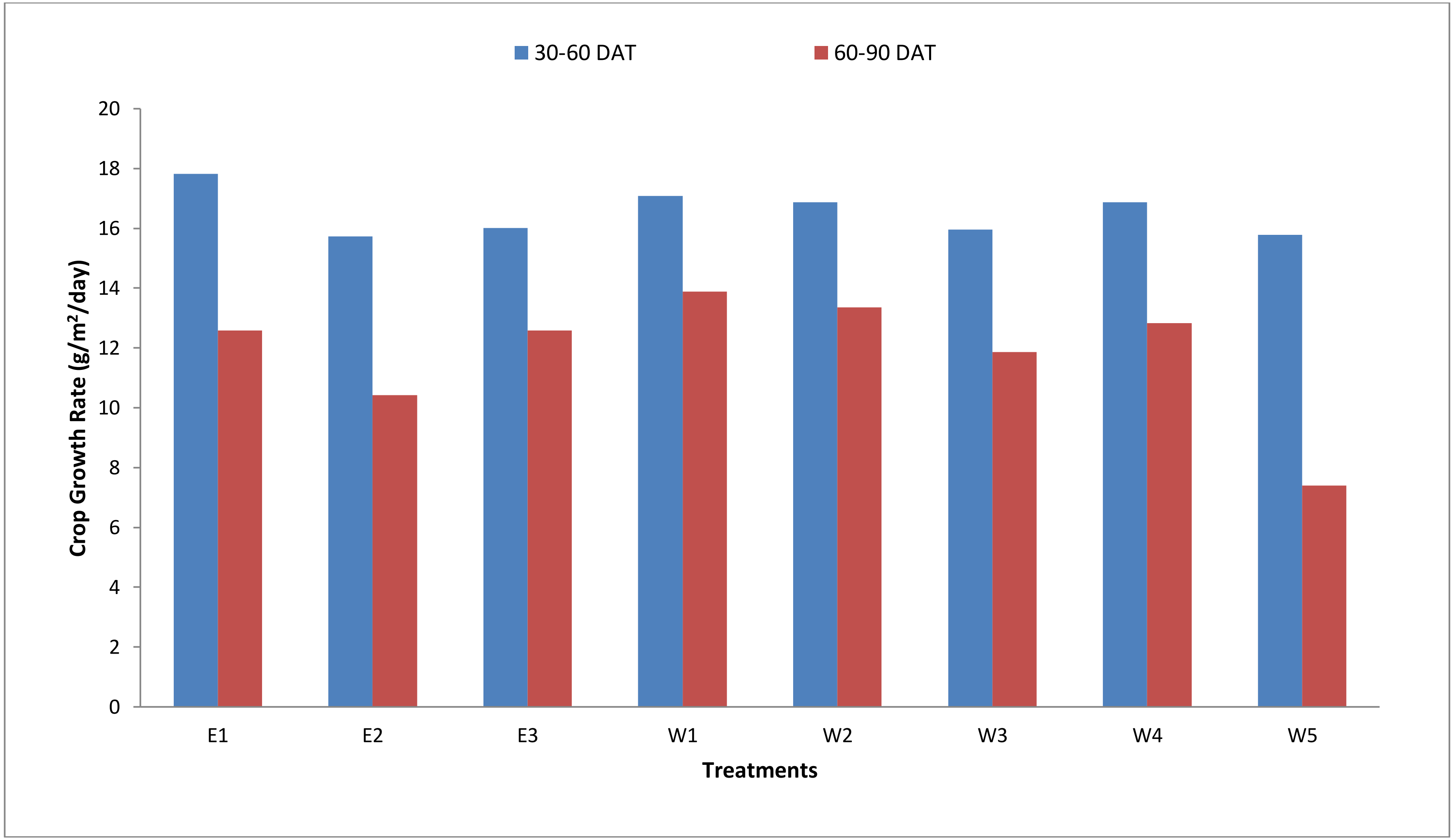


Fig.4.20 (a): Effect of establishment methods and weed management on Crop Growth Rate (g/m^2/day) (2019)

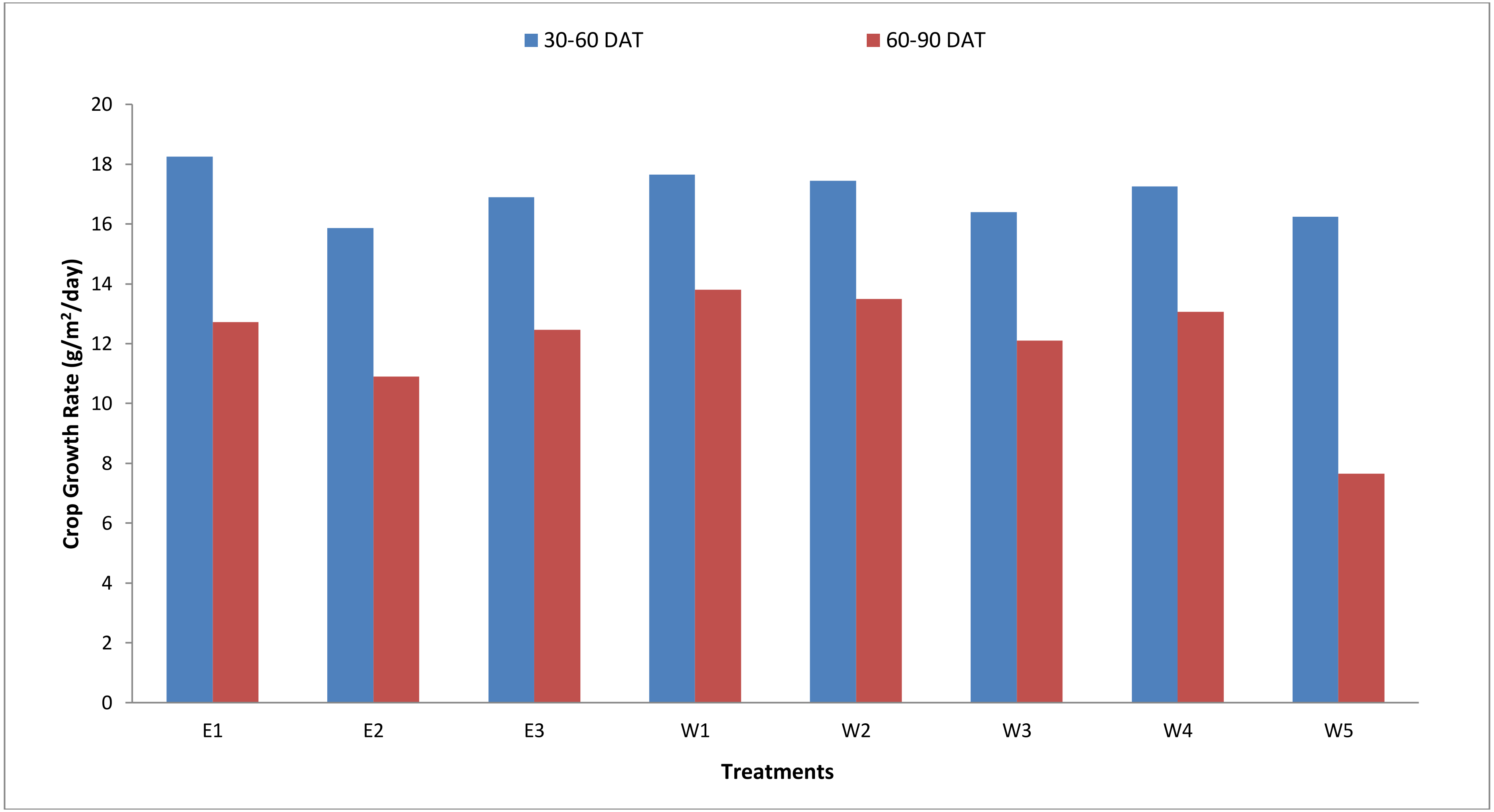


Fig. 4.20(b): Effect of establishment methods and weed management on Crop Growth Rate (g/m^2/day) (2020)

g/m^2/day) was calculated under unpuddled flatmethod (E_2) at 30-60 and 60-90 DAT interval during both the years, respectively.

The weed management practices had significant effect onCGRat different days interval of crop growth during both the years. Among weed control treatments the lowest CGR at 30-60 and 60-90 DAT found in weedy check which was significantly lower than the remaining treatments. The maximumCGR was (17.09, 17.66 and 13.55, 14.17 g/m^2/day) recorded with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} (W_2) and two hand weedings (W_4) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) at 30-60 and 60-90 DAT during both the years.There was no any significant interaction between crop establishment methods and weed management practices on CGR.

4.2.6 Yield attribute

The data pertaining to yield attributes effective tillers (m^2), panicle length (cm), no. of grain panicle^{-1} and 1000-grain weight (g) are presented in Table: 4.22 and illustrated in Fig 4.21 and their analysis of variance is given in Appendix- XXIII.

4.2.7Effective tillers (m^{-2})

Effective tillers (m^2)were significantly influenced by crop establishment methods. The highest effective tiller(182.4 and 182.6 m^{-2}) recorded under conventionalpuddled transplanting (E_1) which was significantly higher than the unpuddled flat (E_2)(163.1 and 170.3m^{-2}) and at par with furrow irrigated raised bed method (E_3) (171.2 and 173.4 m^{-2}) in the year 2019 and 2020 respectively.Effective tillerwas also significantly influenced by weed management practices. The highesteffective tillers (187.1 and 190.4 m^{-2}) were obtained with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g

Table 4.22: Effect of establishment methods and weed managementon yield attributes of Basmati rice

Treatments	Yield attributes							
	Effective tillers (m^2)		Panicle length (cm)		No. of grain per panicle		1000 grain weight (g)	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	182.4	182.6	24.0	24.5	123.5	127.0	19.85	19.96
E_2-Unpuddled Flat (UPF)	163.1	170.3	21.8	21.8	112.9	116.6	18.85	18.98
E_3-Furrow Irrigated Raised Beds (FIRBs)	171.2	173.4	22.9	23.8	119.3	120.6	20.43	20.62
SE(m)±	***3.79***	***3.45***	***0.48***	***0.49***	***2.32***	***2.26***	***0.37***	***0.37***
C.D(P=0.05)	***13.13***	***11.95***	***1.68***	***1.70***	***8.04***	***7.84***	***NS***	***NS***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	187.1	190.4	25.0	25.6	124.6	127.0	20.51	20.90
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	185.1	187.5	24.8	24.8	120.1	123.70	20.47	20.74
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	176.7	182.7	22.5	23.0	117.1	120.3	19.46	19.51
W_4-Two hand weedings	182.5	184.3	24.4	24.7	119.1	123.0	20.05	19.96
W_5-Weedy check	129.6	132.3	18.0	18.8	111.9	113.0	18.08	18.15
SE(m)±	***4.30***	***4.00***	***0.51***	***0.53***	***2.35***	***2.41***	***0.41***	***0.41***
C.D(P=0.05)	***12.78***	***11.90***	***1.52***	***1.60***	***6.99***	***7.16***	***1.22***	***1.23***

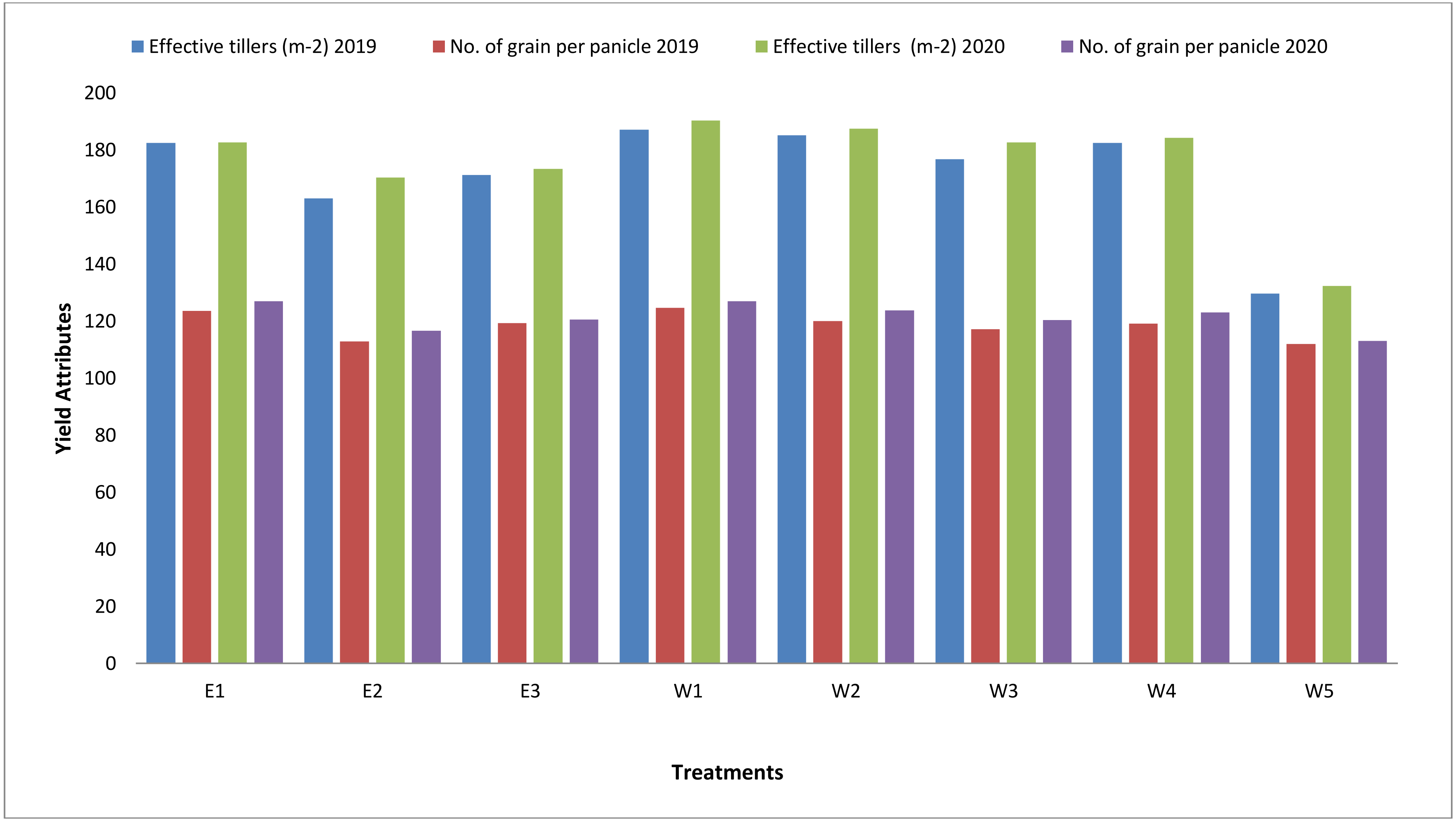


Fig.4.21 (a): Effect of establishment methods and weed management on yield attributes of Basmati rice (2019- 2020)

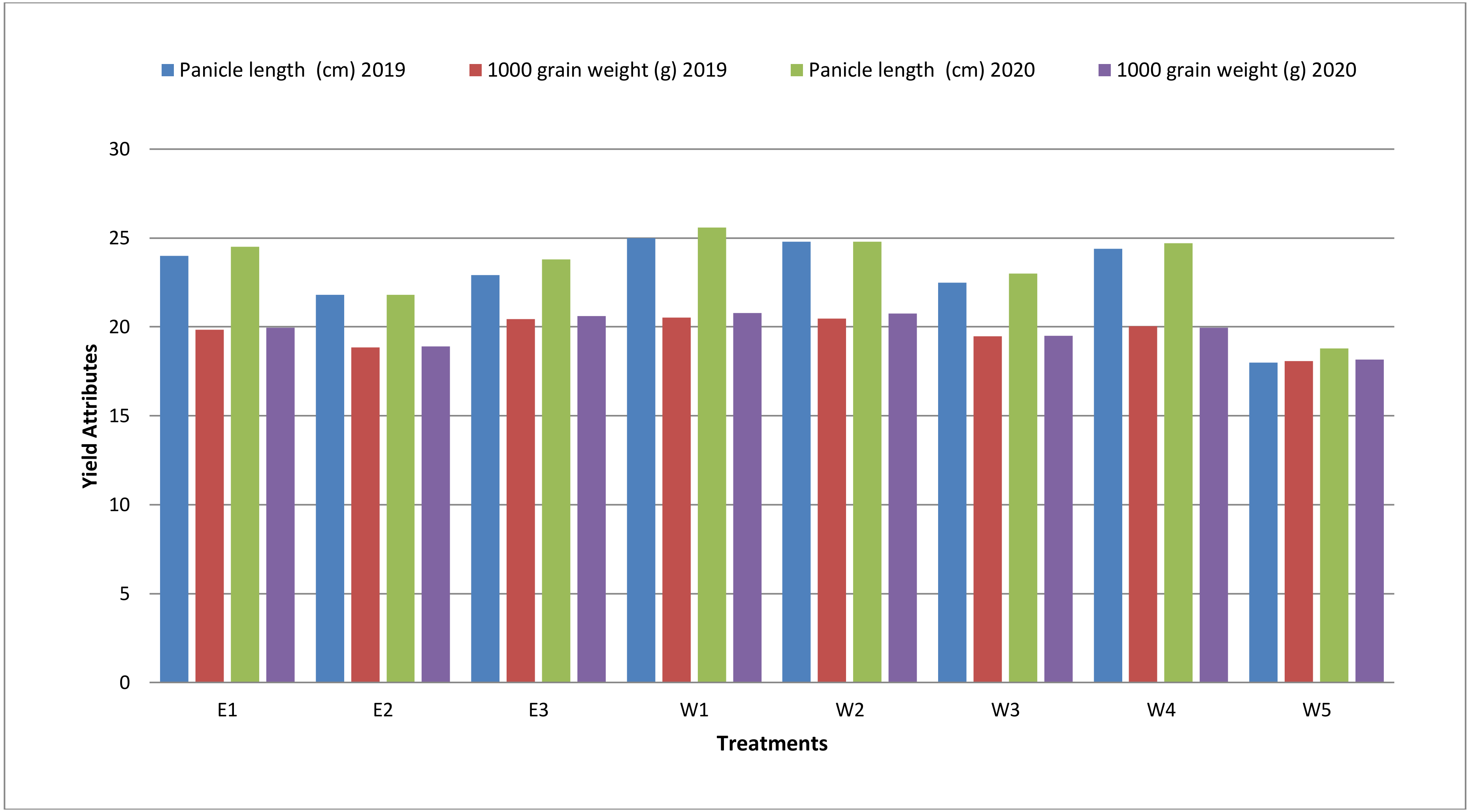


Fig.4.21 (b): Effect of establishment methods and weed management on yield attributes of Basmati rice (2019- 2020)

a.i. ha^{-1}(W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) and two hand weedings (W_2) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) in the year 2019 and 2020, respectively. However lowest effective tillers(129.6 and 132.3 m^{-2}) were obtained in weedy check (W_5).There was no any significant interaction between crop establishment methods and weed management practices oneffective tillers.

4.2.8Panicle length (cm)

Panicle length (cm)was significantly influenced by crop establishment methods. The highest Panicle length (24.0 and 24.5 cm) recorded under conventional puddled transplanting (E_1) which was significantly higher than the unpuddled flat (E_2) (21.8 and 21.8cm) and at par with furrow irrigated raised bed method (E_3) (22.9 and 23.8cm) in the year 2019 and 2020, respectively.Panicle length was also significantly influenced by weed management practices. The highest Panicle length(25.0 and 25.6cm) was obtained with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} (W_2) and two hand weedings (W_4) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) in the year 2019 and 2020, respectively. However lowest Panicle length (18.0 and 18.8 cm) was obtained in weedy check (W_5).There was no any significant interaction between crop establishment methods and weed management practices onpanicle length.

4.2.9Number of grain panicle^{-1}

No. of grain panicle^{-1}was significantly influenced by crop establishment methods. The highestno. of grain (123.5 and 127.0) recorded under conventional puddled transplanting (E_1) which was significantly higher than the unpuddled flat (E_2) (112.9 and 116.6) and at par with furrow irrigated raised bed method (E_3) (119.3 and 120.6) in the year 2019 and 2020 respectively.No. of grain panicle^{-1}was also significantly influenced by weed management practices. The highestno. of grain(124.6 and 127.0) was obtained with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) and two hand weedings (W_4) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) in the year 2019 and 2020, respectively. However lowest no. of grain (111.9 and 113.0) was obtained in weedy check (W_5).There was no any significant interaction between crop establishment methods and weed management practices onno. of grain panicle^{-1}.

4.2.101000-grain weight (g)

1000-grain weight (g)was non significantly influenced by crop establishment methods. The highestno. of grain (20.43 and 20.62 g) was recorded underfurrow irrigated raised bed method (E_3)followed by conventional puddled transplanting (E_1) (19.85 and 19.96 g) and the lowest 1000 grain weight (18.85 and 18.90 g) was recorded under unpuddled flat (E_2) in both the year, respectively.1000-grain weight (g)was significantly influenced by weed management practices. The highest 1000-grain weight(20.51and 20.77 g) was obtained with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) and two hand weedings (W_4) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) in the year 2019 and 2020, respectively. However lowest 1000-grain weight(18.08 and 18.15 g) was obtained in weedy check (W_5). There was no any significant interaction between crop establishment methods and weed management practiceson1000-grain weight.

4.3: Yield studies

Data in respect of grain yield, straw yield, biological yield and harvest index are presented in table 4.23, depicted in Fig. 4.22 and their analyses of variance are given in appendix XXIV.

4.3.1 Grain yield (q ha^{-1})

The yield was the ultimate result of final assessment of treatment in any agronomic investigation. Grain yield was significantly influenced by crop establishment methods. The effect of different crop establishment methods on grain yield was significant. The highest grain yield (44.91 and 46.26 q ha^{-1}) recorded under conventional puddled transplanting (E_1) which was significantly higher than the unpuddled flat (E_2) (37.23 and 39.93 q ha^{-1}) and at par with furrow irrigated raised bed method (E_3) (42.97 and 44.08 q ha^{-1}) in the year 2019 and 2020, respectively. Grain yield was also significantly influenced by weed management practices. The highest grain yield (47.36 and 49.48 q ha^{-1}) was obtained with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) and two hand weedings followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) in the year 2019 and 2020, respectively. About 58.54 and 59.87% increase in grain yield due to Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) over weedy checkduring both the years. However, the lowest grain yield (27.72 and 29.62 q ha^{-1}) was obtained in weedy check (W_5). About 41.46 and 40.13 % reduction in grain yield recorded due to weeds in both the year respectively.There was no any significant interaction effect between crop establishment methods and weed management practices ongrain yield.

Table 4.23: Effect of establishment methods and weed management on grain, straw, biological yield and harvest index of Basmati rice

Treatments	Yield (q ha^{-1})						Harvest index (%)	
	Grain		Straw		Biological			
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E_1-Conventional Puddled Transplanting (CPT)	44.91	46.26	76.40	77.74	121.31	124.00	36.90	37.17
E_2-Unpuddled Flat (UPF)	37.23	39.93	65.10	70.30	102.33	110.23	36.17	36.06
E_3-Furrow Irrigated Raised Beds (FIRBs)	42.97	44.08	73.22	73.82	116.19	117.90	36.76	37.23
SE(m)±	***0.89***	***0.86***	***1.44***	***1.38***	***2.07***	***2.32***	***0.71***	***0.71***
C.D(P=0.05)	***3.08***	***3.01***	***4.99***	***4.78***	***7.18***	***8.04***	***NS***	***NS***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	47.36	49.48	79.63	82.40	126.99	131.88	37.29	37.51
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	46.21	47.57	78.84	80.16	125.05	127.72	36.94	37.21
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	41.17	43.00	71.85	75.41	113.02	118.41	36.39	36.29
W_4-Two hand weedings	46.05	47.45	74.35	76.42	120.40	123.87	38.23	38.29
W_5-Weedy check	27.72	29.62	53.20	55.38	80.92	85.00	34.21	34.81
SE(m)±	***0.88***	***0.84***	***1.38***	***1.41***	***2.19***	***2.25***	***0.69***	***0.68***
C.D(P=0.05)	***2.63***	***2.52***	***4.12***	***4.19***	***6.53***	***6.68***	***2.05***	***2.03***

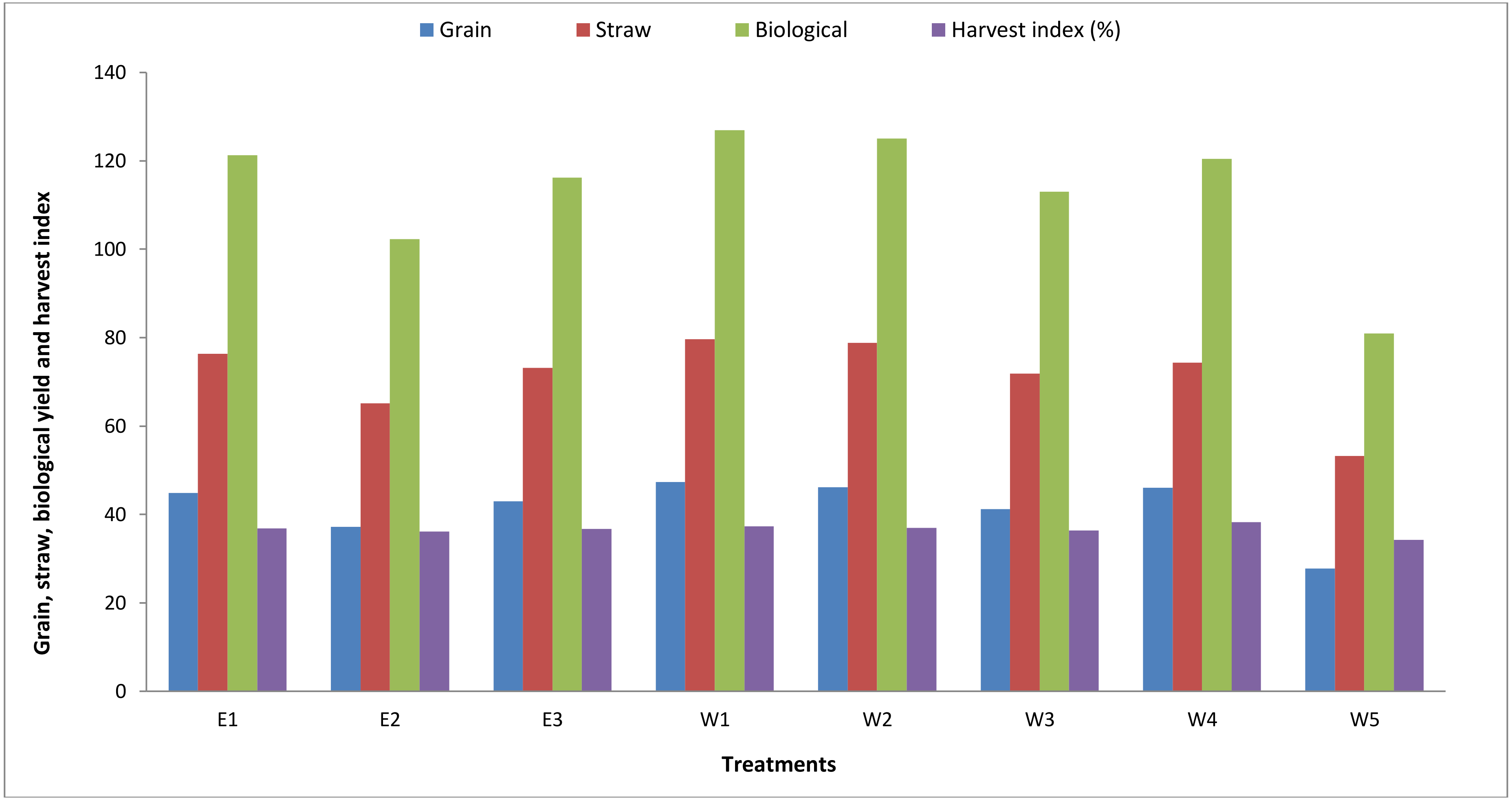


Fig.4.22 (a): Effect of establishment methods and weed management on grain, straw, biological yield and harvest index of Basmati rice (2019)

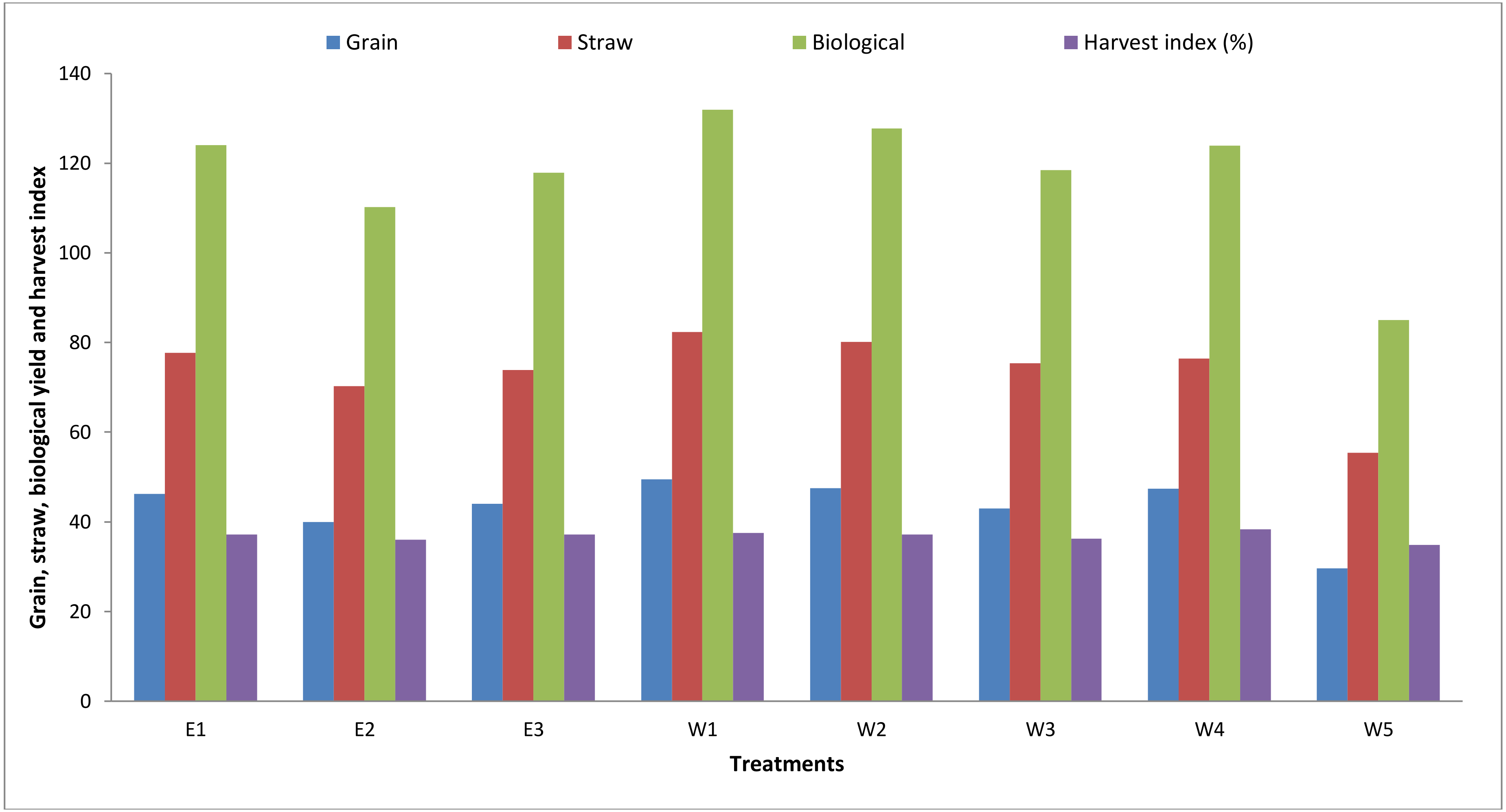


Fig.4.22 (b): Effect of establishment methods and weed management on grain, straw, biological yield and harvest index of Basmati rice (2020)

4.3.2 Straw yield (q ha^{-1})

Straw yield was significantly influenced by crop establishment methods.The effect of different crop establishment methods on straw yield was significant. The highest straw yield (76.40 and 77.74 q ha^{-1}) recorded under conventionalpuddled transplanting (E_1) which was significantly higher than the unpuddled flat (E_2) (65.10 and 70.30 q ha^{-1}) and at par with furrow irrigated raised bed method (E_3) (73.22 and 73.82 q ha^{-1}) in the year 2019 and 2020 respectively.

Straw yield was also significantly influenced by weed management practices. The highest straw yield (79.63 and 82.40 q ha^{-1}) was obtained with pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) and two hand weedings (W_4) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) in the year 2019 and 2020, respectively.About 79.12 and 81.78% increase in straw yield due topretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) over weedy check (W_5) during both the years. However, the lowest straw yield (53.20 and 55.38 q ha^{-1}) was obtained in weedy check (W_5). About 33.19 and 32.79 % reduction in straw yield recorded due to weeds in both the year respectively. There was no any significant interaction effect between crop establishment methods and weed management practices onstraw yield.

4.3.3 Biological Yield (q ha^{-1})

Biological yield was significantly influenced by crop establishment methods.The effect of different crop establishment methods on biological yield was significant. The highest biological yield (121.31 and 124.00 q ha^{-1}) recorded under conventionalpuddled transplanting (E_1) which was significantly higher than the unpuddled flat (E_2) (102.33 and 110.23 q ha^{-1}) and at par with furrow irrigated raised bed method (E_3) (116.19 and 117.90 q ha^{-1}) in the year 2019 and 2020, respectively.

Biological yield was also significantly influenced by weed management practices. The highest biological yield (126.99 and 131.88 q ha^{-1}) was obtained with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} (W_2) and two hand weedings (W_4) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) in the year 2019 and 2020, respectively. About 64.32 and 64.05% increase in biological yield due toPretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} over weedy check (W_5) during both the years However the lowest biological yield (80.92 and 85.00 q ha^{-1}) was obtained in weedy check (W_5). About 56.93 and 55.15 % reduction in biological yield recorded due to weeds in both the year, respectively.There was no any significant interaction between crop establishment methods and weed management practices onbiological yield.

4.3.4 Harvest index (%)

Harvest indexwas non significantly influenced by crop establishment methods. The highest harvest index(36.90 and 37.17 %) recorded under conventionalpuddled transplanting (E_1) which was higher than thefurrow irrigated raised bed method (E_3) and unpuddled flat (E_2) in the year 2019 and 2020, respectively. Harvest indexwas significantly influenced by weed management practices. The highest harvest index(38.23 and 38.29 %) was obtained withtwo hand weedings (W_4) which was statistically at par withPretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) and Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) and followed by Bispyribac sodium @ 25 g a.i. ha^{-1} (W_3) in the year 2019 and 2020, respectively. However, the lowest harvest index(34.21 and 34.81%) was obtained in weedy check.There was no any significant interaction between crop establishment methods and weed management practices onharvest index.

4.4 Nutrients studies

4.4.1 Nitrogen, phosphorus and potassium content in weeds

The mean data pertaining to nitrogen, phosphorus and potassium content in weed as influenced by different treatments are summarized in Table: 4.24 and illustrated in Fig 4.23 and their analysis of variance is given in Appendix- XXV.Data reveals that nitrogen, phosphorus and potassium content in weeds was non significantly affected with crop establishment methods during both the years of experimentation. The maximum N, P and K contents in weeds was (1.024, 0.206, 1.195 and 1.044, 0.226, 1.219) recorded underunpuddled flat method (E_2) followed byfurrow irrigated raised bed method (E_3). However, the lowest nitrogen, phosphorus and potassium content (0.99, 0.200,1.164 and 1.010, 0.219, 1.194) was found under conventional puddled transplanting (E_1) method during 2019 and 2020, respectively.

The weed management practices had significant effect onnitrogen, phosphorus and potassium contentin weeds during both the years. All the treatments caused reduction in nitrogen, phosphorus and potassium contents in weed as compared to weedy check. The minimumnitrogen, phosphorus and potassium content were recorded with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) which was statistically at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} (W_2) and two hand weedings (W_4) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) during both the years.There was no any significant interaction between crop establishment methods and weed management practices onnitrogen, phosphorus and potassium content in weed.

Table 4.24: Effect of establishment methods and weed managementon nutrient content (%) in weeds at harvest

Treatments	Nutrient content of weeds					
	Nitrogen		Phosphorus		Potassium	
	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods						
E_1-Conventional Puddled Transplanting (CPT)	0.99	1.010	0.200	0.219	1.164	1.194
E_2-Unpuddled Flat (UPF)	1.024	1.044	0.206	0.226	1.195	1.219
E_3-Furrow Irrigated Raised Beds (FIRBs)	1.009	1.029	0.202	0.220	1.176	1.202
SE(m)±	***0.008***	***0.008***	***0.002***	***0.002***	***0.010***	***0.009***
C.D(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
(W) Weed Management Options						
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	0.947	0.967	0.178	0.198	1.065	1.095
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	0.963	0.983	0.184	0.205	1.098	1.128
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	1.058	1.078	0.211	0.237	1.258	1.287
W_4-Two hand weedings	0.968	0.988	0.201	0.210	1.174	1.199
W_5-Weedy check	1.102	1.121	0.238	0.257	1.295	1.315
SE(m)±	***0.009***	***0.009***	***0.002***	***0.002***	***0.010***	***0.011***
C.D(P=0.05)	***0.026***	***0.026***	***0.005***	***0.006***	***0.030***	***0.031***

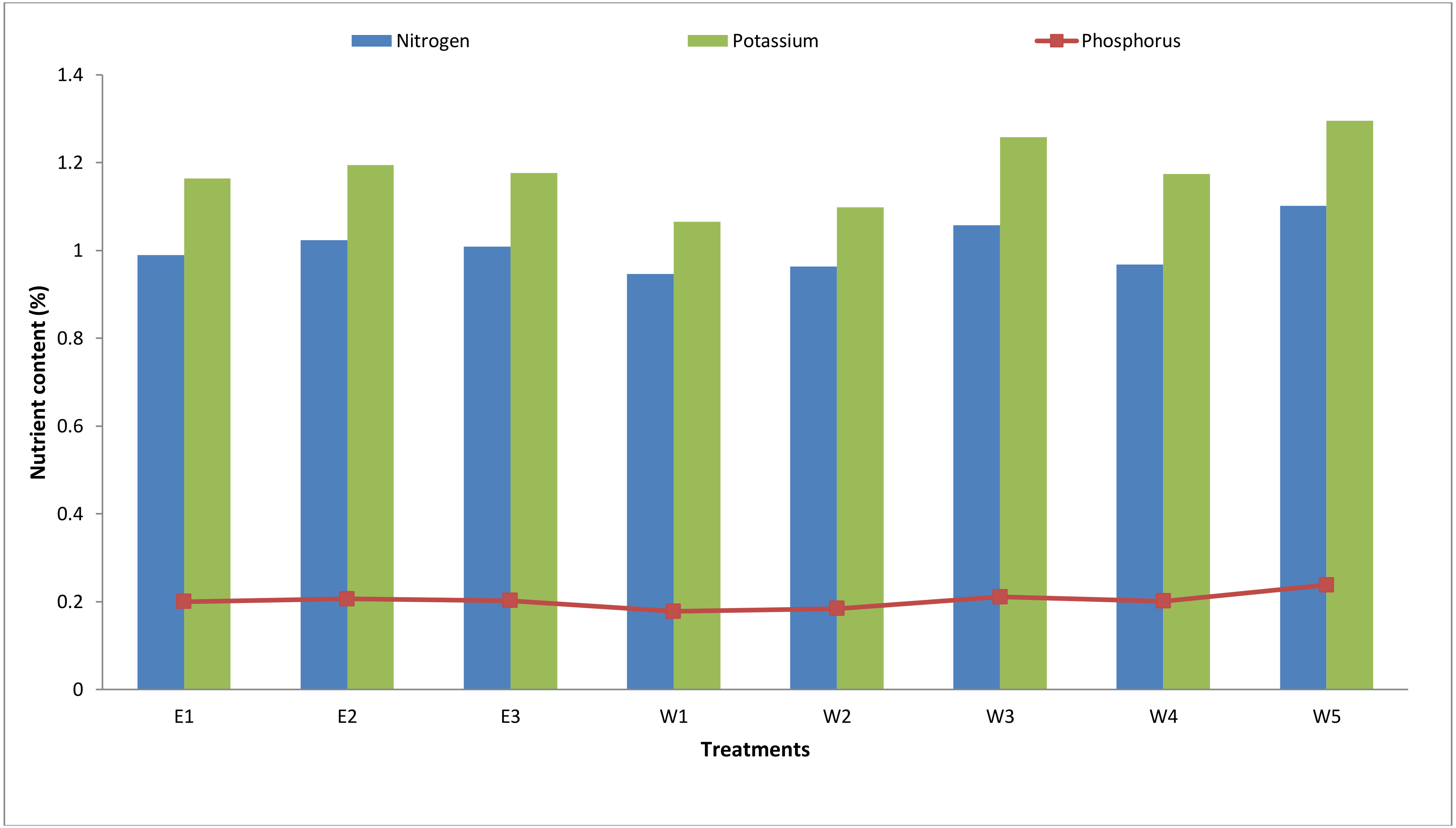


Fig.4.23 (a): Effect of establishment methods and weed management on nutrient content (%) in weeds at harvest (2019)

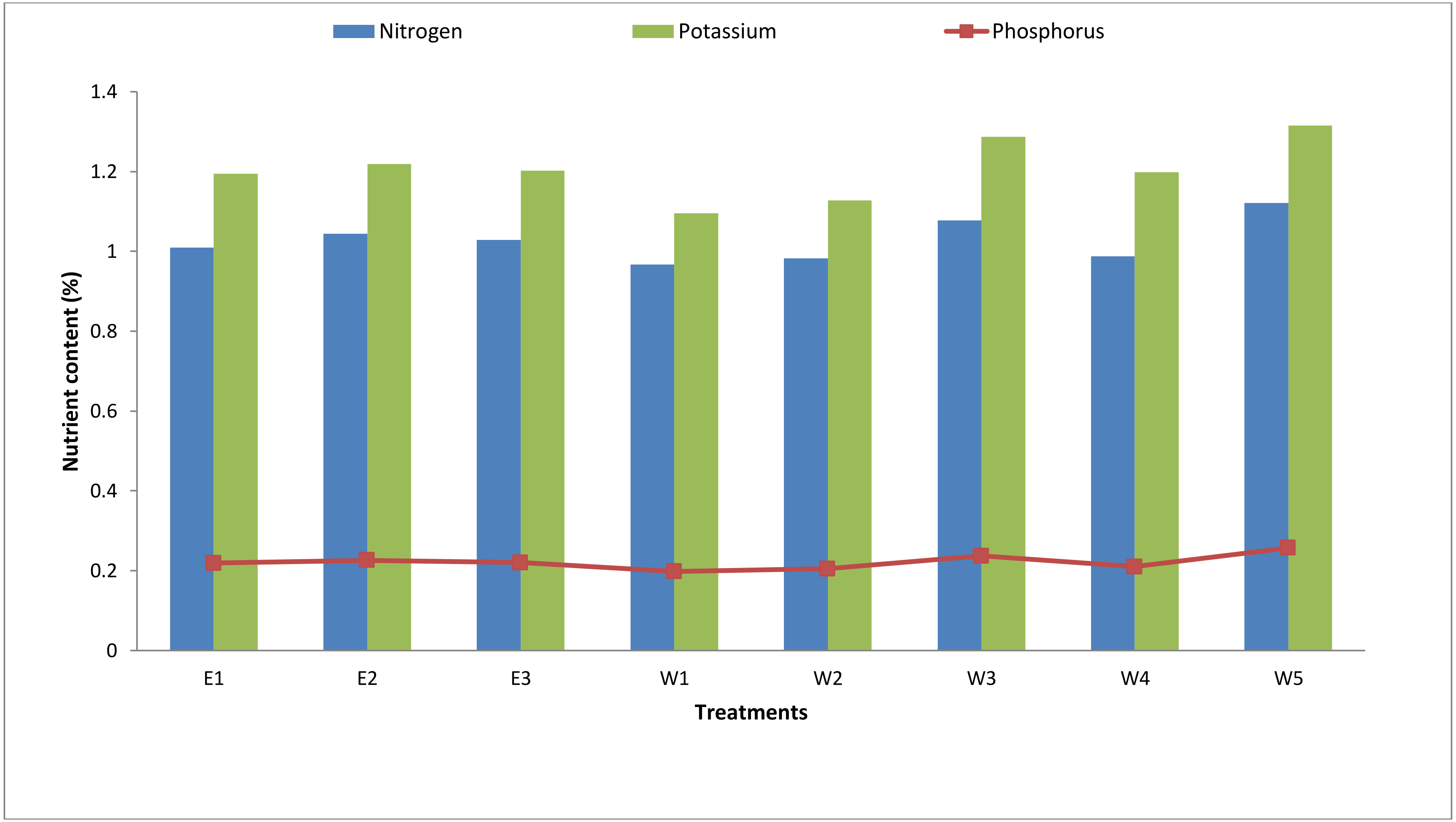


Fig.4.23 (b): Effect of establishment methods and weed management on nutrient content (%) in weeds at harvest (2020)

Table 4.25: Effect of establishment methods and weed managementon nutrient uptake (kg ha^{-1}) by weeds at harvest

Treatments	Nutrient uptake by weed					
	Nitrogen		Phosphorus		Potassium	
	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods						
E_1-Conventional Puddled Transplanting (CPT)	4.09	4.48	0.84	1.01	5.08	5.56
E_2-Unpuddled Flat (UPF)	7.13	7.59	1.44	1.65	8.03	8.52
E_3-Furrow Irrigated Raised Beds (FIRBs)	6.50	6.94	1.34	1.53	7.70	8.24
SE(m)±	***0.12***	***0.13***	***0.02***	***0.03***	***0.17***	***0.18***
C.D(P=0.05)	***0.42***	***0.47***	***0.09***	***0.10***	***0.60***	***0.63***
(W) Weed Management Options						
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	2.61	2.95	0.48	0.60	2.97	3.38
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	3.16	3.51	0.60	0.73	3.64	4.08
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	7.86	8.34	1.54	1.81	9.32	9.94
W_4-Two hand weedings	2.41	2.76	0.50	0.59	2.95	3.36
W_5-Weedy check	13.50	14.11	2.92	3.25	15.78	16.44
SE(m)±	***0.33***	***0.35***	***0.08***	***0.08***	***0.25***	***0.26***
C.D(P=0.05)	***1.00***	***1.05***	***0.23***	***0.25***	***0.75***	***0.79***

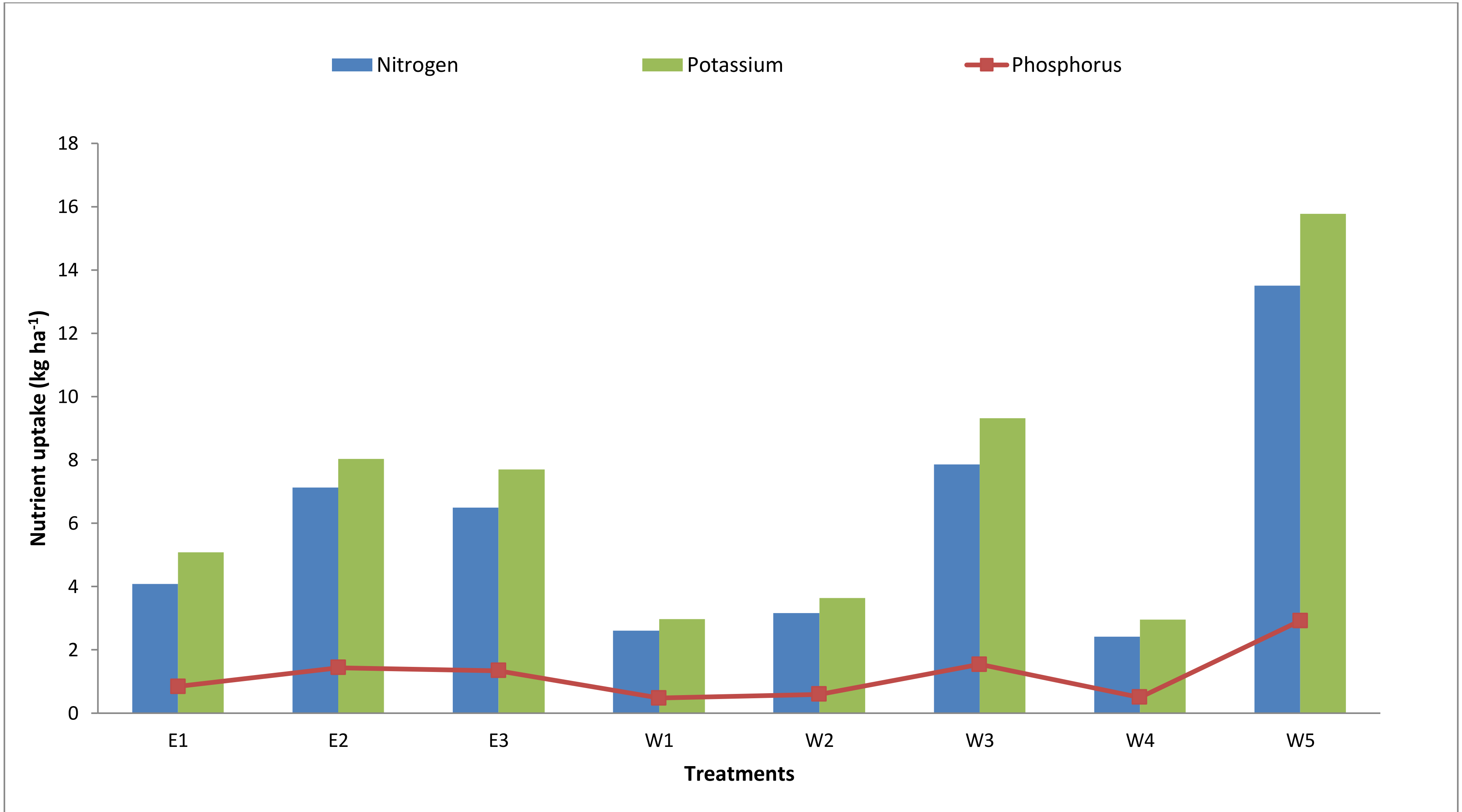


Fig.4.24 (a)Effect of establishment methods and weed management on nutrient uptake (kg ha^{-1}) by weeds at harvest (2019)

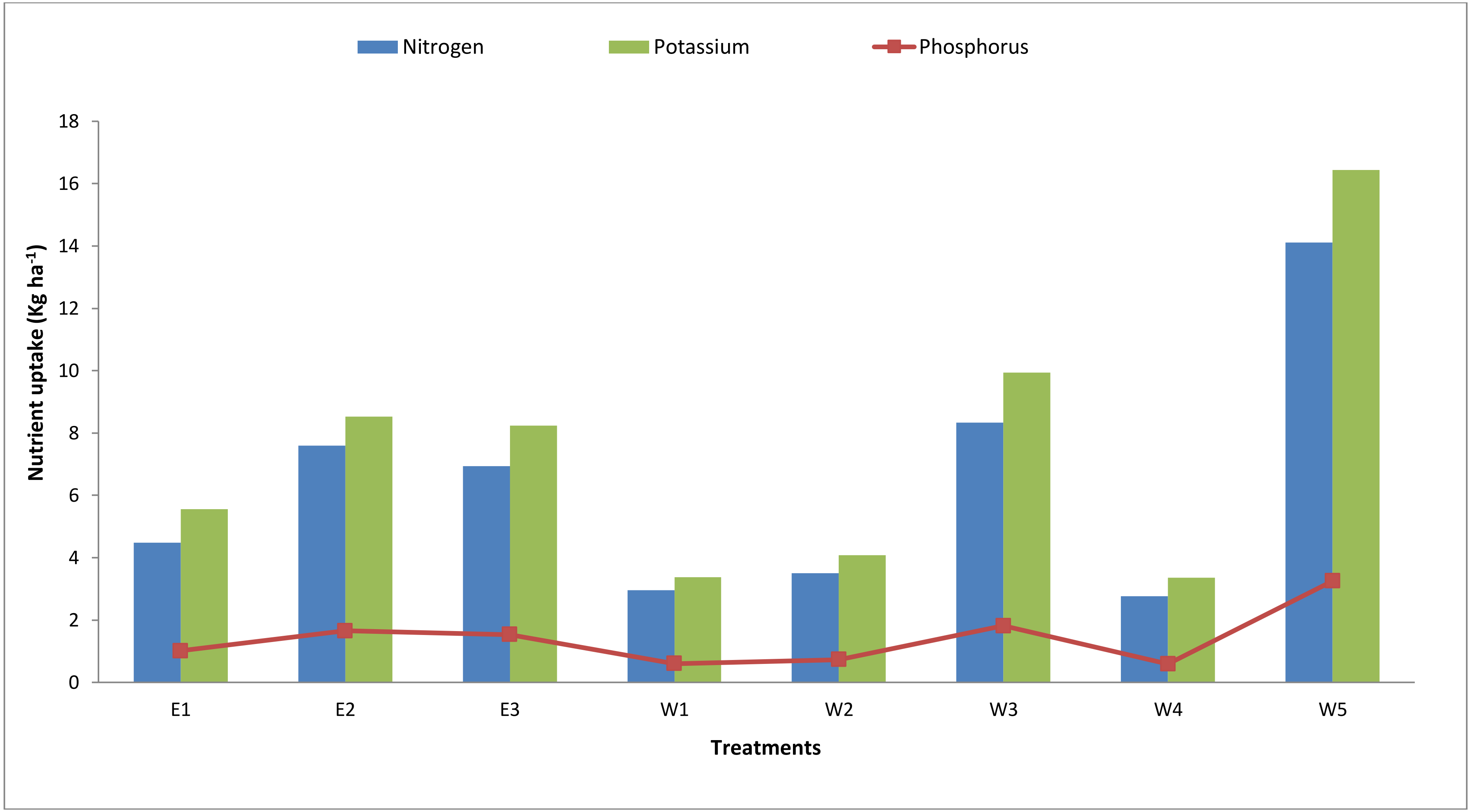


Fig. 4.24(b): Effect of establishment methods and weed management on nutrient uptake (kg ha^{-1}) by weeds at harvest (2020)

4.4.2 Nitrogen, phosphorus and potassium removal by weeds (kg ha^{-1})

The mean data pertaining to nitrogen, phosphorus and potassium removal by weeds (kg ha^{-1})as influenced by different treatments are summarized in Table: 4.26 and illustrated in Fig 4.24 and their analysis of variance is given in Appendix- XXVI.Data reveals that nitrogen, phosphorus and potassium removal by weeds were significantly affected with crop establishment methods during both the years of experimentation. Thenitrogen, phosphorus and potassium removal by weeds under conventional puddled transplanting method (E_1) (4.09, 0.84, 5.08 and 4.48, 1.01, 5.56kg ha^{-1}) was significantly lowest then rest of the treatments during both the years. However, the highest nitrogen, phosphorus and potassium removal by weeds (7.13, 1.44, 8.03 and 7.59, 1.65, 8.52kg ha^{-1}) was obtained under unpuddled flat method (E_2) during 2019 and 2020, respectively.

The weed management practices had significant effect onnitrogen, phosphorus and potassium removal by weeds during both the years. All the treatments caused significant reduction in nitrogen, phosphorus and potassium removal by weed as compared to weedy check. The minimumnitrogen, phosphorus and potassium removal were recorded with two hand weedings(W_4) which was statistically at par with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) and Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} (W_2) followed by Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) during both the years.There was no any significant interaction between crop establishment methods and weed management practices onnitrogen, phosphorus and potassium removal by weed.

4.4.3 Nitrogen content and uptake in grains and straw of rice

The data pertaining to nitrogen content of rice (%) in grains and straw and uptake (in grains, straw and total) is presented in Table 4.26, depicted in Fig. 4.25, and

Table 4.26: Effect of establishment methods and weed managementon nitrogen content (%) and uptake (kg ha^{-1}) by Basmati rice

Treatments	Nitrogen content (%)				Nitrogen uptake (kg ha^{-1})				Total uptake (kg ha^{-1})	
	Grain		Straw		Grain		Straw			
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods										
E_1- Conventional Puddled Transplanting (CPT)	1.10	1.10	0.42	0.43	49.80	51.57	33.02	34.33	82.82	85.90
E_2-Unpuddled Flat (UPF)	1.07	1.08	0.41	0.42	40.52	43.83	27.45	30.32	67.97	74.15
E_3-Furrow Irrigated Raised Beds (FIRBs)	1.11	1.13	0.46	0.45	48.47	50.19	33.77	33.63	82.24	83.82
SE(m)±	***0.009***	***0.009***	***0.004***	***0.004***	***1.32***	***0.73***	***0.88***	***0.48***	***1.18***	***0.66***
C.D(P=0.05)	***0.031***	***0.031***	***0.012***	***0.012***	***4.85***	***2.55***	***3.05***	***1.67***	***4.09***	***2.30***
(W) Weed Management Options										
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.18	1.19	0.49	0.50	55.89	58.82	38.91	41.03	94.80	99.84
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	1.14	1.15	0.45	0.46	52.71	54.67	35.65	37.02	88.36	91.70
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	1.09	1.10	0.43	0.44	45.06	47.47	31.07	33.34	76.13	80.82
W_4-Two hand weedings	1.11	1.12	0.44	0.45	51.31	53.26	32.90	34.51	84.21	87.76
W_5-Weedy check	0.95	0.96	0.35	0.32	26.36	28.43	18.53	17.89	44.89	46.32
SE(m)±	***0.010***	***0.010***	***0.008***	***0.004***	***1.17***	***1.02***	***0.81***	***0.70***	***1.18***	***1.08***
C.D(P=0.05)	***0.029***	***0.029***	***0.023***	***0.011***	***3.48***	***3.05***	***2.41***	***2.08***	***3.52***	***3.23***

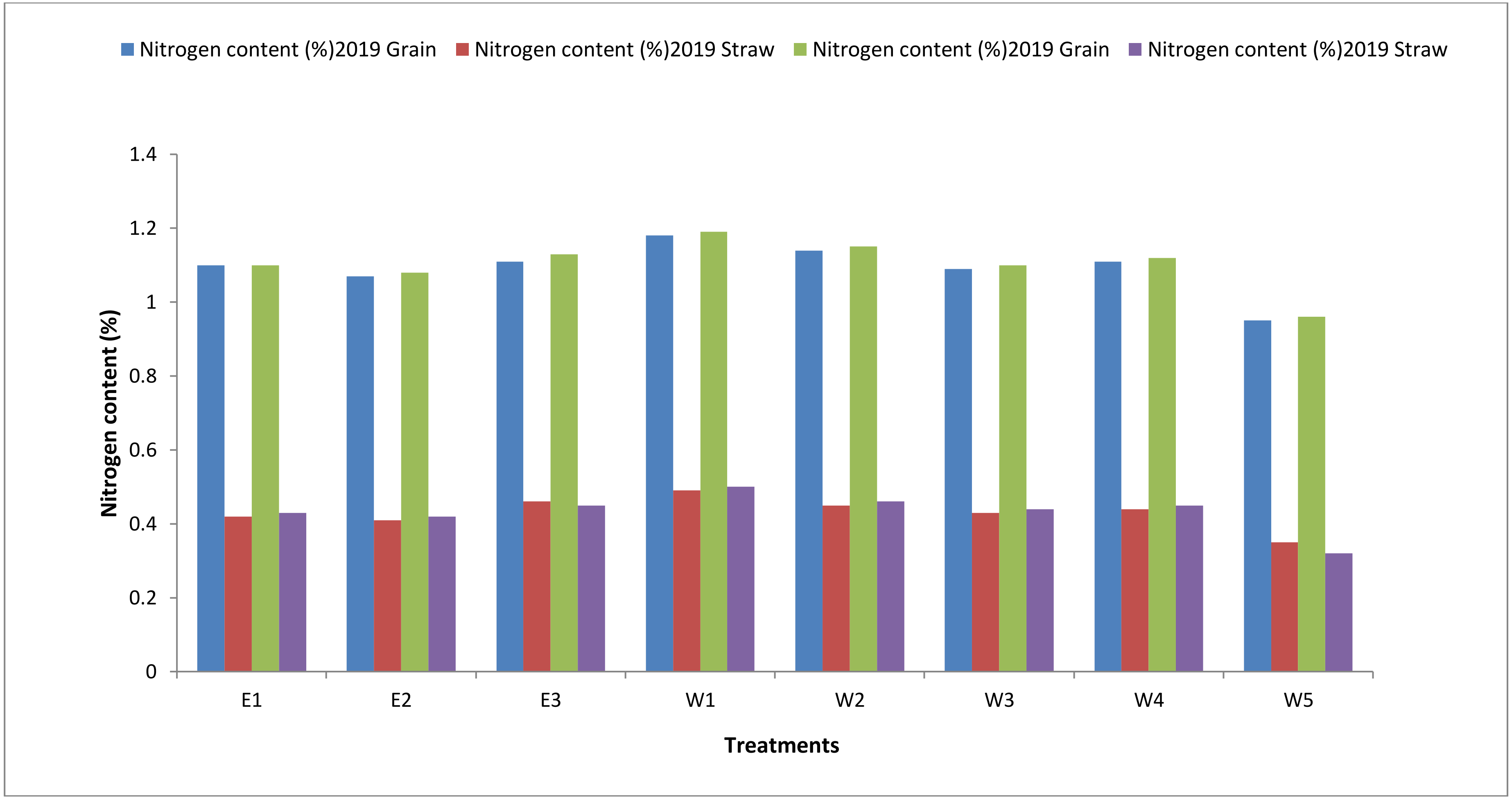


Fig.4.25 (a): Effect of establishment methods and weed management on nitrogen content (%) of basmati rice 2019-2020

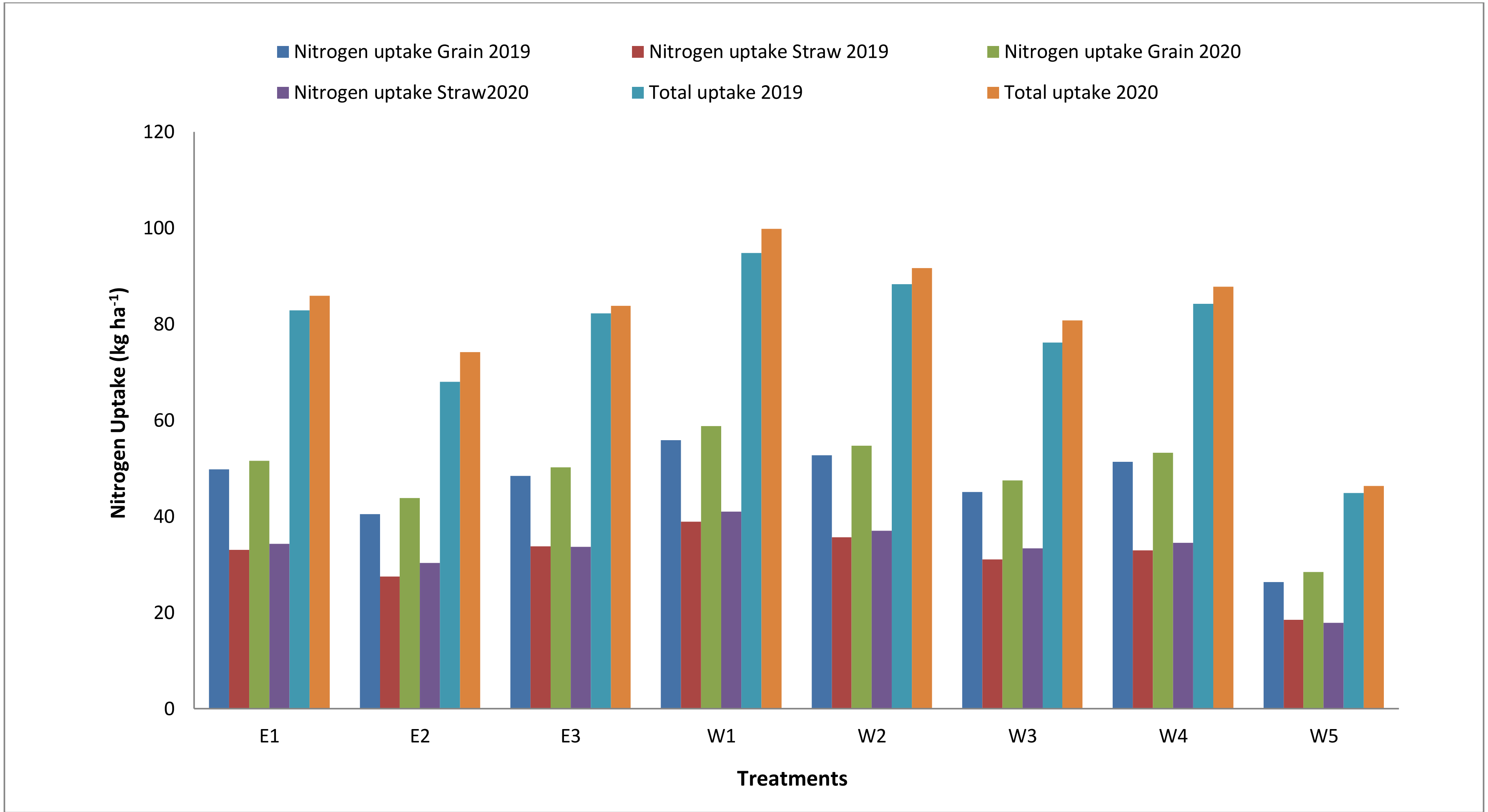


Fig 4.25(b): Effect of establishment methods and weed management on nitrogen uptake (kg ha^{-1}) by Basmati rice 2019-2020

their analysis of variance is given in appendix XXVII. The Data revealed that,in general the nitrogen content was higher in rice grains than straw. The nitrogen content in rice grain, straw and nitrogen uptake in rice grain and straw was significantly influenced with crop establishment methods during both the years of experimentation. The maximum N, content (1.11 and 1.13) in rice grain, (0.46 and 0.45) in rice strawwas recorded underfurrow irrigated raised bed method (E_3) and the maximum uptake of nitrogen (49.80 and 51.57) in rice grain, (33.02 and 34.33) in rice straw and total uptake were recorded underconventionalpuddled transplanting (E_1) followed byfurrow irrigated raised bed method (E_3). However, the lowest nitrogen content in grain and straw (1.07, 1.08 and 0.41, 0.42) and lowest nitrogen uptake in grain and straw (40.52, 43.83 and 27.45, 30.32) was found under unpuddled flat method (E_2) during 2019 and 2020, respectively.

The weed management practices had significant effect onnitrogen content (in grain and straw) and uptake (in grains, straw and total) during both the years. The maximum nitrogen, content (1.18 and 1.19) in grain, (0.49 and 0.50) in straw and maximum nitrogen uptake (55.89 and 58.82) in grain, (38.91 and 41.03) in straw and total uptake were recorded with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) followed by Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2), two hand weedings (W_4) and Bispyribac sodium @ 25 g a.i. ha^{-1}(W_4).However, the lowest nitrogen content (0.95, 0.96 and 0.35, 0.32) and uptake (26.36, 28.43 and 18.53, 17.89) in grain and straw was found under weedy check (W_5) during 2019 and 2020, respectively.There was no any significant interaction effect between crop establishment methods and weed management practices onnitrogen content of rice (%) in grains and straw and uptake (in grains, straw and total).

Table 4.27: Effect of establishment methods and weed managementon phosphorus content (%) and uptake (kg ha^{-1}) by Basmati rice

Treatments	Phosphorus content (%)				Phosphorus uptake (kg ha^{-1})				Total uptake (kg ha^{-1})	
	Grain		Straw		Grain		Straw			
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods										
E_1-Conventional Puddled Transplanting (CPT)	0.35	0.38	0.17	0.17	15.60	17.57	13.00	13.52	28.59	31.09
E_2-Unpuddled Flat (UPF)	0.34	0.37	0.16	0.17	12.72	14.99	10.71	12.14	23.46	27.13
E_3-Furrow Irrigated Raised Beds (FIRBs)	0.35	0.39	0.17	0.18	15.19	17.09	12.41	13.06	27.60	30.15
SE(m)±	***0.003***	***0.003***	***0.001***	***0.001***	***0.22***	***0.35***	***0.27***	***0.28***	***0.16***	***0.43***
C.D(P=0.05)	***NS***	***NS***	***NS***	***NS***	***0.76***	***1.21***	***0.93***	***0.98***	***0.58***	***1.50***
(W) Weed Management Options										
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	0.37	0.40	0.18	0.18	17.54	20.02	14.25	14.57	31.80	34.60
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	0.35	0.39	0.17	0.18	16.22	18.53	13.41	14.37	29.63	32.90
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	0.33	0.37	0.16	0.17	13.77	15.96	11.39	12.65	25.16	28.61
W_4-Two hand weedings	0.35	0.38	0.17	0.18	15.93	17.90	12.56	13.64	28.48	31.53
W_5-Weedy check	0.33	0.35	0.16	0.17	9.12	10.33	8.57	9.32	17.69	19.65
SE(m)±	***0.004***	***0.004***	***0.004***	***0.003***	***0.34***	***0.37***	***0.42***	***0.35***	***0.50***	***0.51***
C.D(P=0.05)	***0.013***	***0.01***	***0.012***	***0.010***	***1.02***	***1.11***	***1.25***	***1.04***	***1.50***	***1.51***

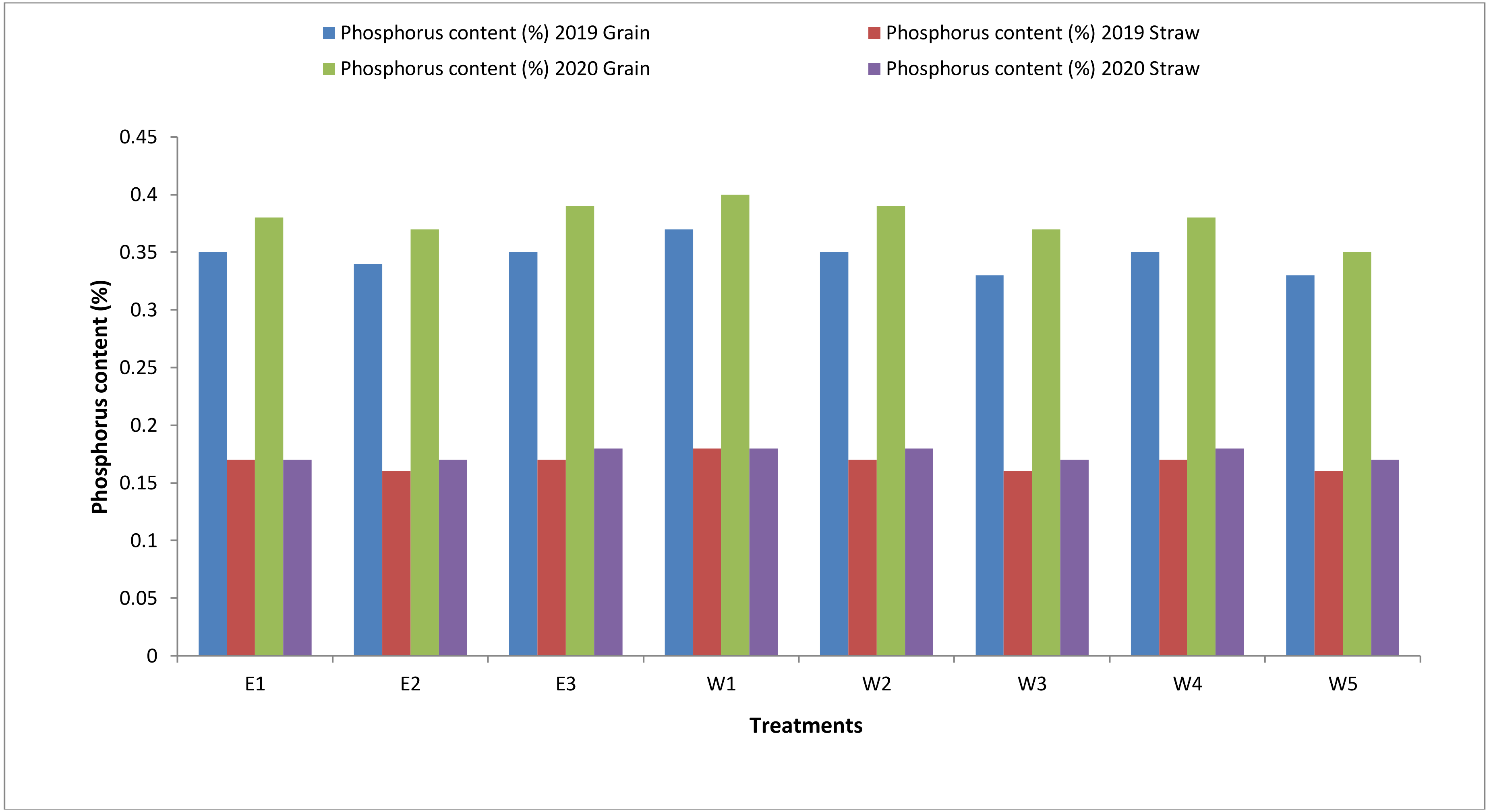


Fig.4.26 (a): Effect of establishment method and weed management on phosphorous content (%) of basmati rice 2019-2020

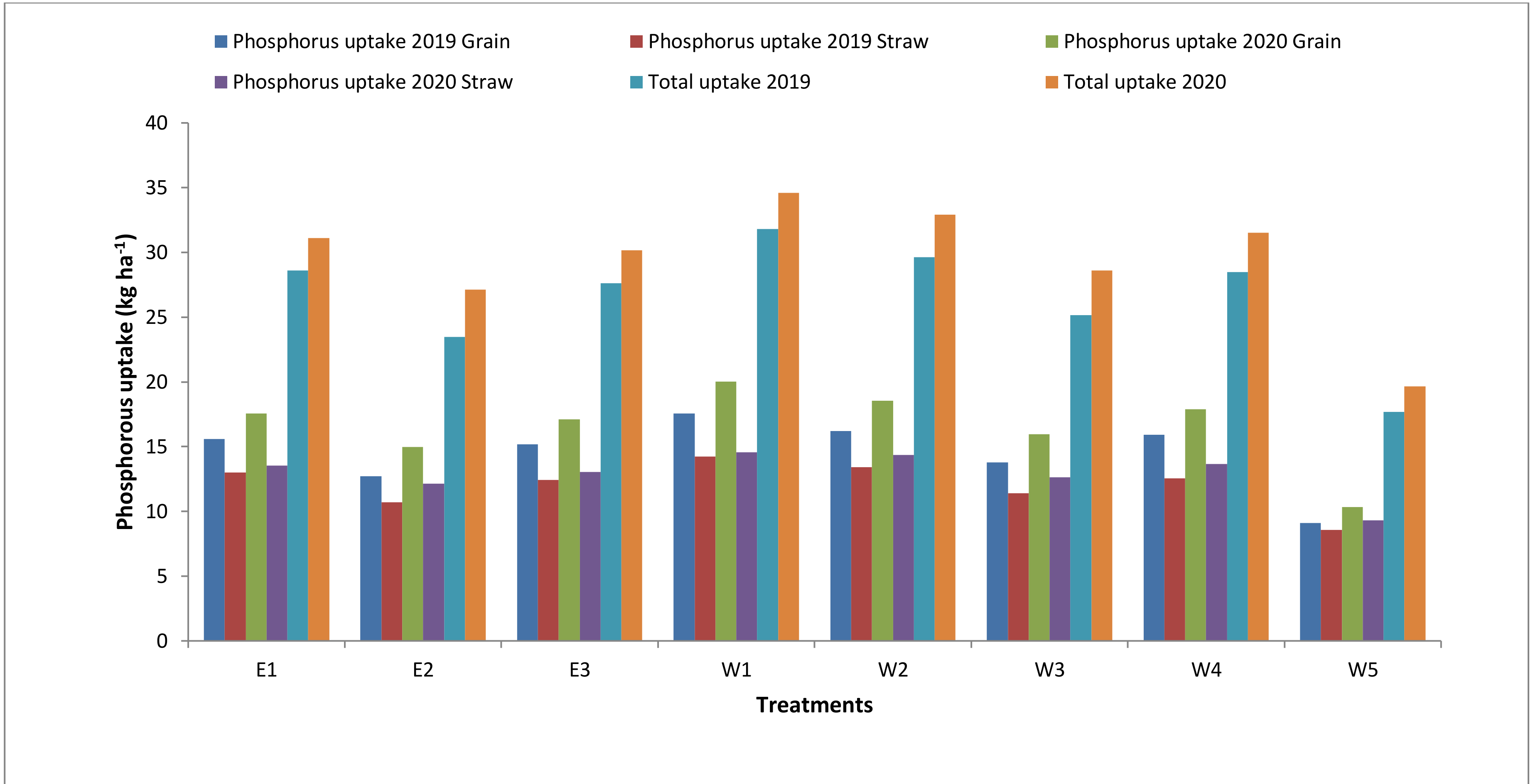


Fig.4.26 (b): Effect of establishment methods and weed management on phosphorous uptake (kg ha^{-1}) of basmati rice 2019-2020

4.4.4Phosphorus content and uptake in grains and straw of rice

The data pertaining to phosphorus content of rice (%) in grains and straw and uptake (in grains, straw and total) is presented in Table 4.27, depicted in Fig. 4.26, and their analysis of variance is given in appendix XXVIII. The Data revealed that,the phosphorus content in rice grains and straw was non significantly influenced with crop establishment methods while phosphorus uptake in rice grain, straw and total were significantly influenced with crop establishment methods during both the years of experimentation. The maximumphosphorus, content (0.35 and 0.39) in rice grain, (0.17 and 0.18) in rice straw recorded underfurrow irrigated raised bed method (E_3)and the maximum uptake ofphosphorus (15.60 and 17.57) in rice grain, (13.00 and 13.52) in rice straw and total uptake (28.59 and 31.09) were recorded underconventionalpuddled transplanting (E_1). However, the lowest phosphorus content in grain and straw (0.34, 0.37 and 0.16, 0.17) and lowestphosphorus uptake in grain and straw (12.72, 14.99 and 10.71, 12.14) was found under unpuddled flat method (E_2) during 2019 and 2020, respectively.

The weed management practices had significant effect onphosphoruscontent (in grain and straw) and uptake (in grains, straw and total) during both the years. The maximumphosphorus, content (0.37 and 0.40) in grain, (0.18 and 0.18) in straw and maximum phosphorus uptake (17.54 and 20.02) in grain, (14.25 and 14.57) in straw and total uptake were recorded with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) followed by Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2), two hand weedings (W_4) and Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3).However, the lowestphosphorus content (0.33, 0.35 and 0.16, 0.17) and uptake (9.12, 10.33 and 8.57, 9.32) was found under weedy check (W_5) during 2019 and 2020, respectively. There was no any significant interaction between crop establishment methods and weed management practices onphosphorus content of rice in grains and straw and uptake.

4.4.5Potassium content and uptake in grains and straw of rice

The data pertaining to potassium content of rice (%) in grains and straw and uptake (in grains, straw and total) is presented in Table 4.28, depicted in Fig. 4.27, and their analysis of variance is given in appendix XXIX. The Data revealed that,thepotassium content in rice straw was non significantly influenced with crop establishment methods whilepotassium content in rice grains and uptake in rice grain, straw and total were significantly influenced with crop establishment methods during both the years of experimentation. The maximum, potassium content (0.44 and 0.47) in rice grain, (1.33 and 1.42) in rice strawwere recorded under furrow irrigated raised bed method (E_3) and the maximum uptake ofpotassium (19.72 and 21.97) in rice grain, (101.07 and 109.87) in rice straw and total uptake (120.80 and 131.84) were recorded underconventionalpuddled transplanting (E_1). However, the lowest potassium content in grain and straw (0.42, 0.45 and 1.29, 1.38) and lowest potassiumuptake in grain and straw (16.15, 18.12 and 84.52, 97.49) was found under unpuddled flat method (E_2) during 2019 and 2020, respectively.

The weed management practices had significant effect onpotassium content (in grain and straw) and uptake (in grains, straw and total) during both the years. The maximumpotassium, content (0.49 and 0.49) in grain, (1.39 and 1.48) in straw and maximum potassiumuptake (23.16 and 24.28) in grain, (110.87 and 121.62) in straw and total uptake were recorded with Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1)followed by Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i.

Table 4.28: Effect of establishment methods and weed managementon potassium content (%) and uptake (kg ha⁻¹) by Basmati rice

Treatments	Potassium content (%)				Potassium uptake (kg ha^{-1})				Total uptake (kg ha^{-1})	
	Grain		Straw		Grain		Straw			
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods										
E_1-Conventional Puddled Transplanting (CPT)	0.43	0.46	1.31	1.40	19.72	21.97	101.07	109.87	120.80	131.84
E_2-Unpuddled Flat (UPF)	0.42	0.45	1.29	1.38	16.15	18.12	84.52	97.49	100.67	115.60
E_3-Furrow Irrigated Raised Beds (FIRBs)	0.44	0.47	1.33	1.42	19.36	20.73	98.26	105.35	117.62	126.08
SE(m)±	***0.004***	***0.004***	***0.011***	***0.011***	***0.47***	***0.39***	***2.26***	***1.92***	***2.11***	***1.77***
C.D(P=0.05)	***0.012***	***0.013***	***NS***	***NS***	***1.64***	***1.35***	***7.82***	***6.64***	***7.32***	***6.15***
(W) Weed Management Options										
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	0.49	0.49	1.39	1.48	23.16	24.28	110.87	121.62	134.03	145.90
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	0.47	0.49	1.35	1.43	21.73	23.34	106.59	114.88	128.33	138.23
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	0.45	0.46	1.31	1.39	18.36	19.83	94.29	104.96	112.64	124.79
W_4-Two hand weedings	0.46	0.48	1.33	1.41	21.27	22.67	98.76	107.52	120.03	130.19
W_5-Weedy check	0.27	0.38	1.17	1.30	7.54	11.23	62.58	72.20	70.11	83.43
SE(m)±	***0.004***	***0.012***	***0.012***	***0.013***	***0.45***	***0.64***	***1.91***	***2.38***	***1.91***	***2.36***
C.D(P=0.05)	***0.012***	***0.035***	***0.035***	***0.038***	***1.33***	***1.91***	***5.69***	***7.09***	***5.68***	***7.02***

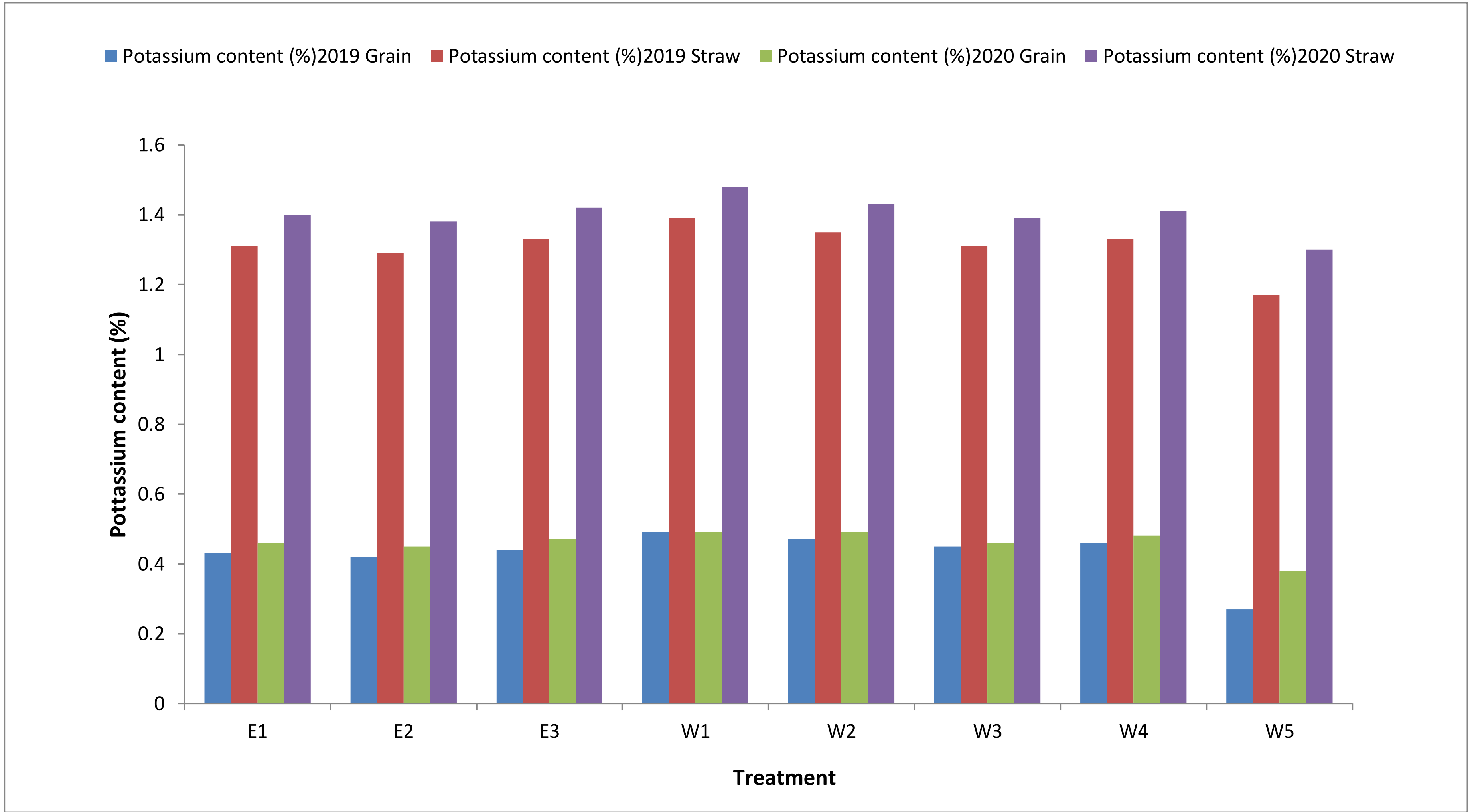


Fig.4.27 (a): Effect of establishments methods and weed management on potassium content (%) of basmati rice 2019-2020

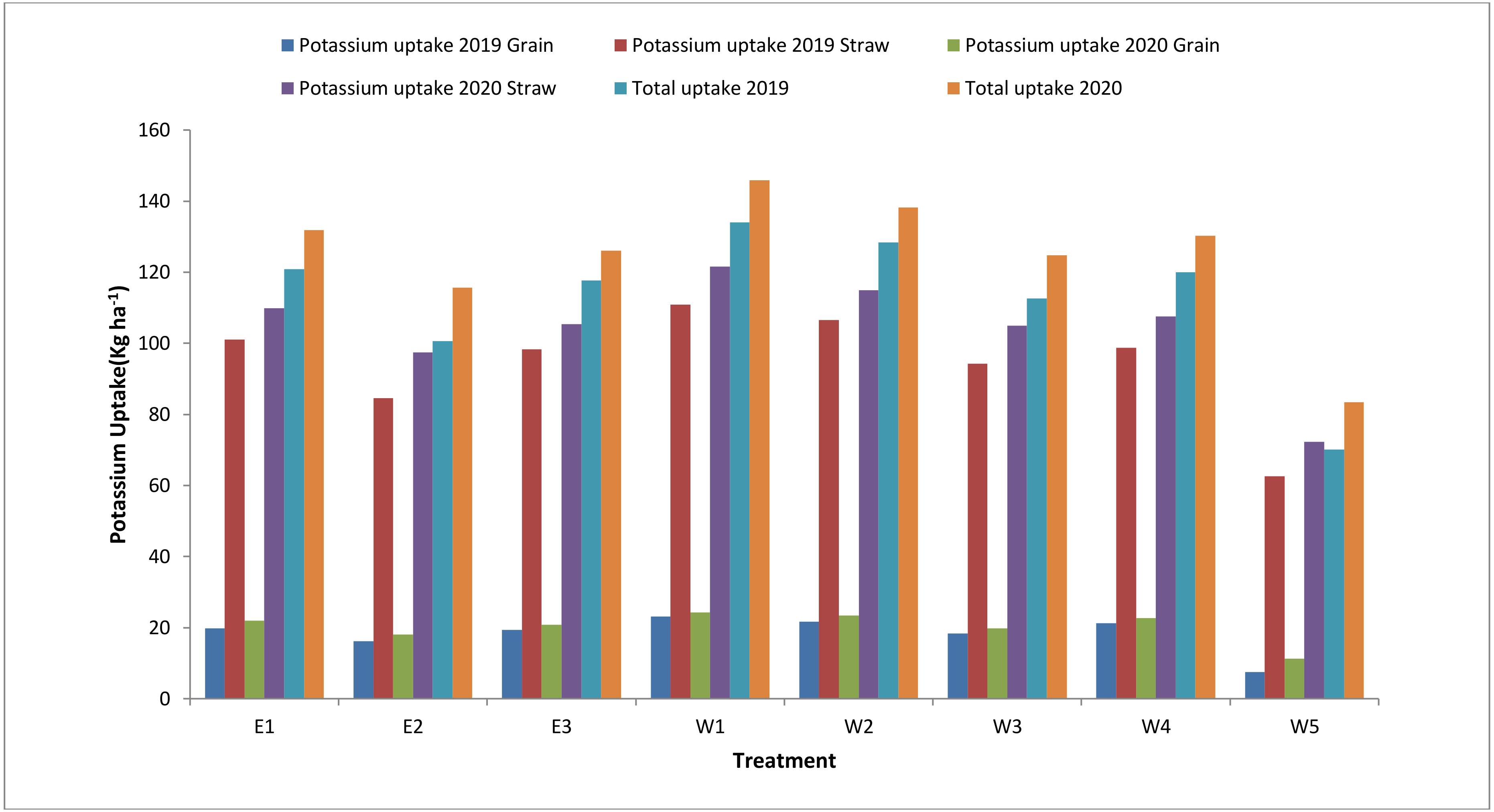


Fig.4.27 (b): Effect of establishment methods and weed management on potassium uptake (kg ha $^{-1}$) of basmati rice 2019-2020

ha^{-1}(W_2), two hand weedings (W_4) and Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3).However, the lowestpotassiumcontent (0.27, 0.38 and 1.17, 1.30) and uptake (7.54, 11.23 and 62.58, 72.20) was found under weedy check (W_5) during 2019 and 2020, respectively.There was no any significant interaction between crop establishment methods and weed management practices onpotassiumcontent of rice (%) in grains and straw and uptake (in grains, straw and total).

4.5 SoilStudies

4.5.1 Bulk density (BD)

Bulk density (BD) affects crop performance in various ways including controlling soil moisture availability, aeration and root penetration. The mean value of BD for conventional puddled transplanted rice and unpuddled flat transplanted rice plots were 1.68 and 1.62 Mg m^{-3}, respectively (Table 4.29). The BD of furrow irrigated raised beds (E_3) was found to be lower than that of conventional puddled transplanted rice (E_1) during experimentation. The low BD indicated the good physical conditions of furrow irrigated raised beds. The mean BD of soils was 1.68; 1.62, 1.63; 1.52, and 1.55 Mg m^{-3} for CPT, UPF and FIRBs planting system, respectively (Table 4.29).

4.5.2 Soil pH

Soil reaction is an indication of nature of soils whether it is acidic, neutral, or saline/ alkaline and controls the nutrient availability to the plants.Tillage crop establishment methods exhibited non-significant effect on soil pH after harvesting of rice during both the years of study. Perusal of data given in Table 4.29 revealed that the soil pH was higher in conventional puddled transplanted rice plots when compared to other planting techniques. Furrow irrigated raised beds (E_3) and unpuddled flat transplanted rice (E_2) recorded lowest soil pH while highest was registered in conventional puddled transplanted rice (E_1) plots during both the years.

Table 4.29: Effect of establishment methods and weed management on soil properties

Treatments	Bulk Density (Mg m^{-3})										EC (dSm^{-1})		pH	
	2019					2020					2019		2020	
	0-5 cm	**5-10 cm**	**10-15 cm**	**15-20 cm**	**Mean**	**0-5 cm**	**5-10 cm**	**10-15 cm**	**15-20 cm**	**Mean**				
(E) Crop Establishment Methods														
E_1- CPT	1.62	1.64	1.70	1.76	**1.68**	1.59	1.66	1.72	1.75	**1.68**	0.25	0.24	7.9	7.8
E_2- UPF	1.52	1.56	1.67	1.72	**1.62**	1.51	1.59	1.69	1.72	**1.63**	0.23	0.23	7.7	7.6
E_3- FIRBs	1.44	1.48	1.55	1.60	**1.52**	1.47	1.52	1.59	1.61	**1.55**	0.21	0.20	7.6	7.5
Mean	***1.52***	***1.56***	***1.64***	***1.69***		***1.52***	***1.59***	***1.66***	***1.69***		***0.23***	***0.22***	***7.73***	***7.63***

4.5.3 Soil electrical conductivity (dS m^{-1})

Soil electrical conductivity (EC) is a measure of the amount of salts in soil. It is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms. Perusal of data presented in Table 4.29 revealed that the planting techniques with land configuration along with furrow irrigated raised beds (E_3) and unpuddled transplanted flat rice (E_2) resulted in lower value of electrical conductivity while highest electrical conductivity was recorded in conventional puddled transplanted rice (E_1) plots during both the years.

4.5.4Available nitrogen (N) (kg ha^{-1})

Data pertaining to the available nitrogen in soil as influenced by various treatments is presented in Table 4.30 and depicted in Fig 4.28and their analysis of variance is given in appendix XXX. Variations in available nitrogen in soil due to various treatments were statistically significant during both the years. In general, the available nitrogen in soil was higher during 2020 than that of 2019. The crop establishment methods do not influence the available nitrogen in soil significantly during both the years of study. Unpuddled flat transplanting (E_2) recorded the higher available nitrogen in soil (200.36 and 208.38 kgha^{-1}) during 2019 and 2020 respectively. It will be seen from this (Table 4.30) that variations in available nitrogen in soil due to weed management options were statistically significant during both the year of study. The higher available nitrogen in soil in relation to weed management, treatment Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) recorded statistically higher available nitrogen (207.85 and 216.16 kg ha^{-1}) in the year 2019 and 2020 respectively. Treatment Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) was statistically at par with Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium

@ 20 g a.i. ha^{-1}(W_1) during both the year. Treatment weedy check(W_5) recorded lowest available nitrogen in soil during both the years of study. The interaction between crop establishment methods and weed management options was non-significant with respect to available nitrogen in soil during both the years of study.

4.5.5 Available phosphorus (P) (kg ha^{-1})

Data pertaining to the available phosphorous in soil as influenced by various treatments is presented in Table 4.30 and depicted in Fig 4.28 and their analysis of variance is given in appendix XXX.The data indicated that available phosphorus status of the soil after the harvest of experimental crop was not differed significantly due to crop establishment methods, however, the highest available phosphorus was recorded under the Unpuddled flat transplanting (E_2) during both the years. Among the weed management practices, the maximum available phosphorus in soil was recorded inPretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) (16.54 & 16.59 kg ha^{-1}) being at par with W_2Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) and Two hand weedings(W_4), the lowest available phosphorus in soil was recorded in Weedy check(W_5) during both the year of study. The interaction effects were non-significant.

4.5.6 Available potassium (K) (kg ha^{-1})

Data pertaining to the available potassium in soil as influenced by various treatments is presented in Table 4.30 and depicted in Fig 4.28 and their analysis of variance is given in appendix XXX.The data indicated that non-significant difference in available potassium status of the soil after harvest of experimental rice crop was observed with crop establishment methods, however, the highest available potassium was recorded under theUnpuddled flat transplanting (E_2) during both the years. The maximum available potassium in soil was (180.45 & 187.27 kg ha^{-1})recorded in

Table 4.30: Effect of establishment methods and weed managementon available nutrients (kg ha^{-1}) in soil.

Treatments	Available nutrients							
	Nitrogen		Phosphorus		Potassium		Organic carbon (%)	
	2019	2020	2019	2020	2019	2020	2019	2020
(E) Crop Establishment Methods								
E$_1$-Conventional Puddled Transplanting (CPT)	196.93	204.81	14.64	14.96	169.61	176.43	0.47	0.48
E$_2$-Unpuddled Flat (UPF)	200.36	208.38	15.73	15.84	176.84	182.15	0.46	0.47
E$_3$-Furrow Irrigated Raised Beds (FIRBs)	197.98	205.90	15.06	15.23	174.85	180.85	0.47	0.48
SE(m)±	***3.83***	***3.98***	***0.28***	***0.29***	***3.36***	***3.48***	***0.009***	***0.009***
C.D(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
(W) Weed Management Options								
W$_1$-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	207.85	216.16	16.54	16.59	180.45	187.27	0.48	0.49
W$_2$-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	200.00	208.00	15.88	16.06	178.59	185.42	0.47	0.49
W$_3$-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	194.77	202.56	14.59	14.62	174.36	179.59	0.46	0.47
W$_4$-Two hand weedings	197.70	205.61	15.88	16.01	176.98	183.56	0.47	0.48
W$_5$-Weedy check	191.82	199.49	12.84	13.41	158.46	163.21	0.46	0.46
SE(m)±	***3.70***	***3.84***	***0.38***	***0.48***	***3.24***	***3.37***	***0.009***	***0.010***
C.D(P=0.05)	***10.99***	***11.43***	***1.15***	***1.43***	***9.63***	***10.01***	***NS***	***NS***

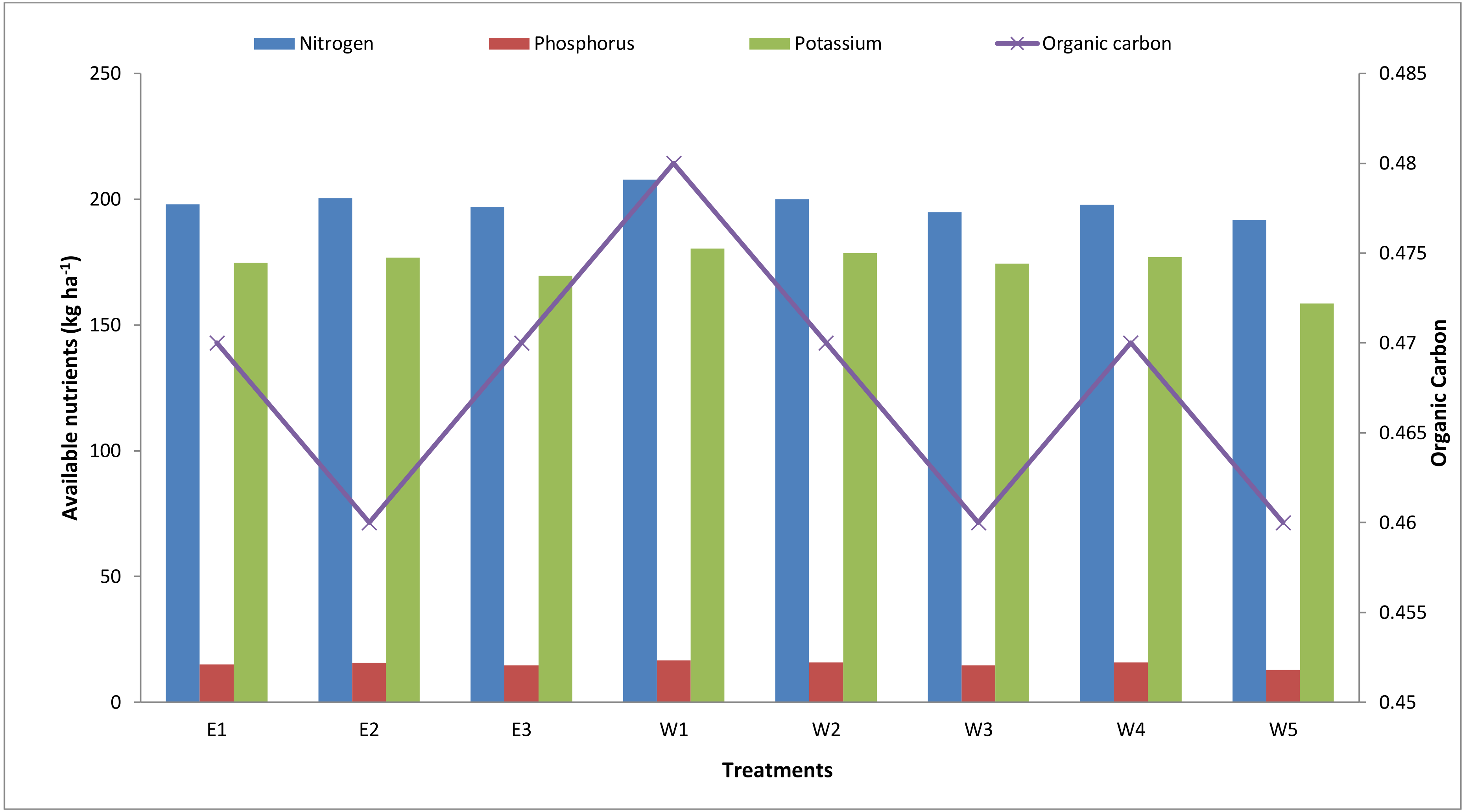


Fig.4.28 (a): Effect of establishment methods and weed management on available nutrients (kg ha^{-1}) in soil (2019)

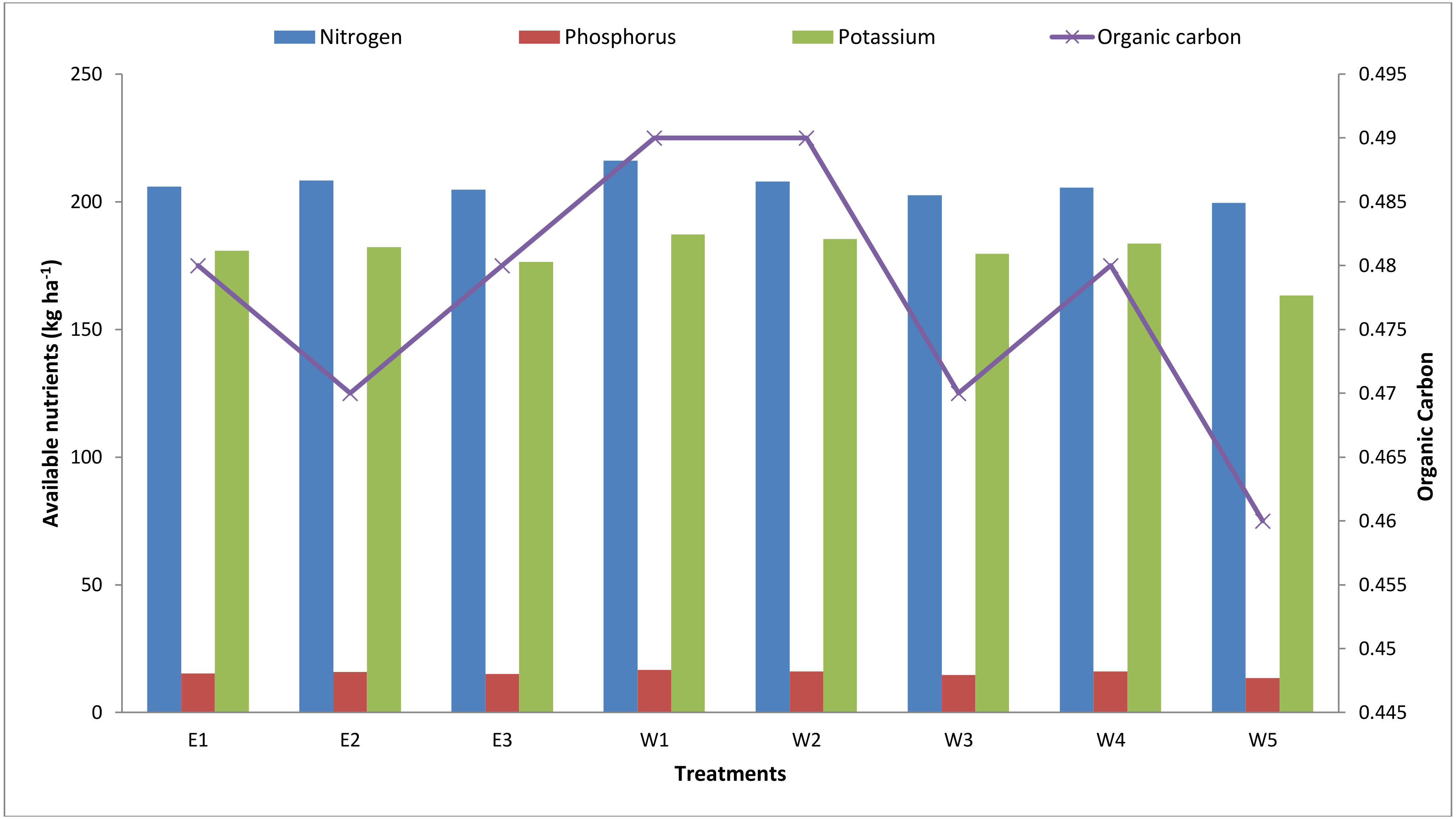


Fig.4.28 (b): Effect of establishment methods and weed management on available nutrients (kg ha^{-1}) in soil (2020)

Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) being at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2), Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3) and Two hand weedings(W_4) in the year 2019 and 2020, respectively, however, the lowest available potassium in soil was recorded in Weedy check(W_5) during both the year of study. The interaction effects were non-significant at all.

4.5.7 Organic carbon in soil (%)

Data pertaining to the organic carbon in soil as influenced by various treatments is presented in Table 4.30 and depicted in Fig 4.28 and their analysis of variance is given in appendix XXX.The data of organic carbon content in plough layer of soil after harvest revealed that both, the crop establishment methods and weed management options did not vary significantly to organic carbon content of the soil during both the year of study. In term of crop establishment methods, higher organic carbon content was obtained withConventional puddled transplanting (E_1) and furrow irrigated raised bed (E_3) closely followed by Unpuddled flat transplanting methods (E_2) during both the years. Different weed management options applied to basmati rice had failed to impart any significant effect on organic carbon content in plough layer of the soil after harvest, however the maximum organic carbon content was recorded in Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) treatment and the lowest in Weedy check(W_5) during both the years of study. All interaction effects were non-significant.

4.6Economics

The economics of rice crop affected by different crop establishment methods and weed management options is depicted in Table 4.31 and Fig 4.29and their analysis of variance is given in appendix XXXI.

4.6.1 Cost of cultivation

Different crop establishment methods have significantly influenced the cost of cultivation of rice, the cost of cultivation was highest in conventionalPuddled transplanted rice (E_1) followed by unpuddled flat (E_2) and the lowest values calculated under furrow irrigated raised beds (E_3) plots during both the year. Among weed management options highest cost of cultivation (Rs. 43111 & 44131) was involved in two hand weedings(W_4) in the year 2019 and 2020, respectively. The lowest cost of cultivation was associated with weedy check(W_5) in both the year of study.

4.6.2 Gross return

In term of gross return, among the different crop establishment methods, the highest gross return was recorded in conventionalPuddled transplanted rice(E_1) followed by furrow irrigated raised beds(E_3) and it was lowest in unpuddled flats(E_2) during both the year of study. This may be because of comparatively higher increase in grain yield. In term of different weed management options, the highest gross return was recorded inPretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) followed by Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) and Two hand weedings(W_4) and the lowest gross return was recorded in Weedy check(W_5) during both the year of study.

4.6.3 Net return

Among the different crop establishment methods, the highest net return was recorded in furrow irrigated raised beds(E_3) followed by conventionalpuddled transplanted rice (E_1) and it was lowest in unpuddled flats(E_2) during both the year of study. In term of different weed management options, the highest net return was recorded inPretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1)

Table 4.31: Effect of establishment methods and weed management on Economics of Basmati rice

Treatments	Economics of rice							
	Cost of Cultivation		Gross Return		Net Return		B:C	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
(E) Crop Establishment Methods								
E_1- Conventional Puddled Transplanting (CPT)	41993	43230	126527	130075	84534	86845	3.01	3.00
E_2-Unpuddled Flat (UPF)	36689	37726	105225	112911	68536	75184	2.86	2.99
E_3-Furrow Irrigated Raised Beds (FIRBs)	35813	36600	121027	123920	85214	87320	3.37	3.38
SE(m)±	-	-	***2128.34***	***2064.25***	***2128.29***	***2064.27***	***0.051***	***0.053***
C.D(P=0.05)	-	-	***7508.20***	***7282.12***	***7508.03***	***7282.17***	***0.182***	***0.186***
(W) Weed Management Options								
W_1-Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	37804	38824	132726	138540	94922	99716	3.51	3.58
W_2-Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} POE at 20 DAT	37151	38171	129716	133345	92565	95174	3.50	3.50
W_3-Bispyribac sodium @ 25 g a.i. ha^{-1} POE at 20 DAT	37167	38187	115850	121073	78683	82886	3.12	3.17
W_4-Two hand weedings	43111	44131	128508	132380	85397	88249	2.98	3.00
W_5-Weedy check	35591	36611	81164	86171	45573	49559	2.28	2.36
SE(m)±	-	-	***2113.15***	***2021.26***	***2113.09***	***2021.29***	***0.056***	***0.052***
C.D(P=0.05)	-	-	***6085.54***	***5820.91***	***6085.36***	***5821.01***	***0.161***	***0.149***

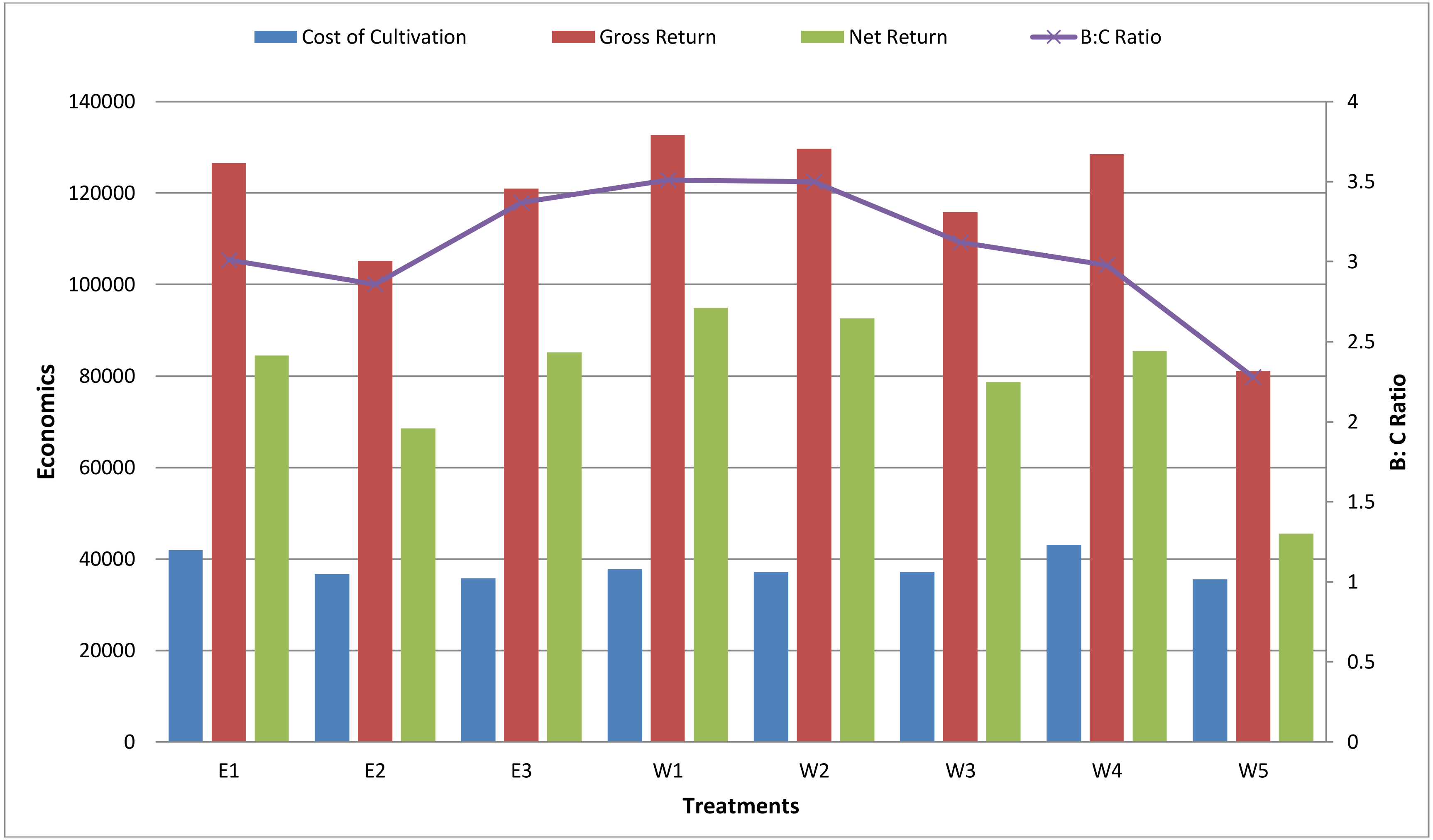


Fig. 4.29(a):Effect of establishment methods and weed management on Economics of Basmati rice(2019)

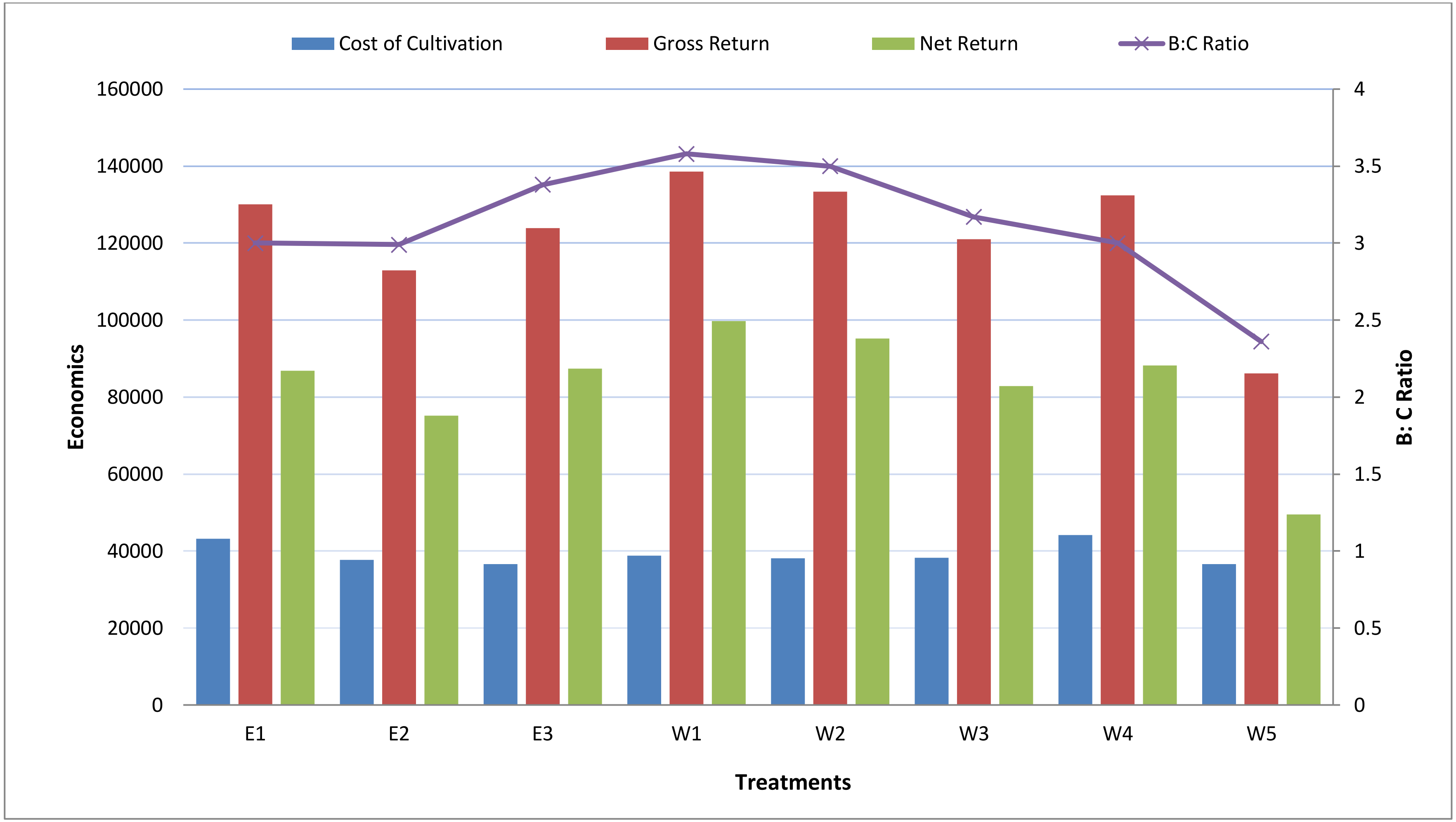


Fig.4.29 (b):Effect of establishment methods and weed management on Economics of Basmati rice (2020)

followed by Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) and Two hand weedings(W_4) and the lowest gross and net return was recorded in Weedy check(W_5) during both the year of study.

4.6.4 Benefit: Cost Ratio:

Among the different crop establishment methods, the B:C ratio was highest in furrow irrigated raised beds (E_3)followed byconventionalpuddled transplanted rice(E_1) and it was lowest in unpuddled flat plots during both the year. Among weed management options highest B:C ratio was observed with the application of Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (3.96 & 4.00) in the year 2019 and 2020, respectively. The lowest B:C ratio was associated with weedy check(W_5) during both the year of study.

CHAPTER – 5 DISCUSSION

The findings presented in the preceding chapter provided a detailed account of the performance in terms of growth, development, yield and yield contributing characters of rice as influenced by weed management treatments. Attempts have been made to evaluate and explain the important observations recorded in the course of present investigation in terms of "cause" and "effect" relationship as far as possible in light of scientific reasoning and to find out the information of practical value. The phenomenon of growth and development of plants mainly depends on genetic make-up, soil environment and climatic conditions. The relationship between agriculture and soil is better understood than between agriculture and climate. It may not be possible to change the climate but it is possible to adopt particular agriculture practice, which aims at higher and sustainable production of crop under prevailing weather situations. In recent years uncertainties in rainfall, the swings in the onset, continuity and withdrawal pattern of monsoon make crop production more risky**(Singh, 2001).**For introducing a suitable management practice, it is necessary to know the yield reduction level of plant and weed intensity in different scenario of weed management practices. In addition, it is necessary to optimize yield and weed control efficiency through proper weed control practices.

5.1 Effect of soil, weather on crop performance

Perusal of data on crop performance in preceding chapter indicates that the crop performed better. The soil was sandy loam in texture, low in organic carbon and nitrogen, while medium in available potassium and high in available phosphorus. The weather conditions have greater significance for rice crop production, which requires optimum precipitation, temperature and humidity during vegetative phase during the reproductive phase for higher yield. The temperature, solar radiation and rainfall are known to influence rice yield directly by affecting the physiological processes involved in grain production. The weather details have been given in Appendix I & II and depicted in Fig. 3.1a & 3.1b. The meteorological data revealed that the weather parameters, in general, were favorable for the crop, although the amount of total rainfall received during crop season were 631.8 and 419.8 mm the crop growth period the mean weekly maximum and minimum temperatures range from 40.3 & 38.5^{0}C to 15.9 & 16.1^{0}C, and mean maximum and minimum relative humidity varied from 95.8 and 88.1% to 46.8 and 41.7% during experimentation 2019 and 2020, respectively.

5.2.1 Effect of crop establishment methods and weed management options on the crop growth

The growth in terms of plant height, number of tillers, dry matter accumulation, LAI and CGR, are given in Table 4.17, 4.18, 4.19, 4.20, and 4.21, shows that the growth was slightly more during 2020 than 2019. This higher growth might be due to more favorable weather condition prevailed like rainfall, sunshine hours, and temperature (Appendix I & II). The effect of different growth parameters was negligible at early vegetative stage and it increased at later stage of crop development. Among the different treatments during both the years of study these variations in growth parameters were because of cumulative seasonal effect and superimposing of different crop establishment methods and weed management treatments.The significantly higher plant growth under conventional puddled transplanting ($E_{1)}$ and furrow irrigated raised beds(E_2) during the years of experimentation in later stages of crop growth was because of more moisture availability to crop plants which have also increased the nutrient uptake, may be the reason of recording higher values of different growth parameters in E_1 and E_3than E_2. The higher amount of available water kept the higher turgor potential, which leads to higher rate of photosynthesis due to larger opening of stomata for longer period of time. This has also increased for faster cell division and enlargement, which leads to higher growth rate. Similar findings were recorded by **Bhuyan *et al.* (2012)**; **Kukal *et al.*, 2009** and **Javaid *et al.* (2012).**

The maximum plant height, number of tillers m^{-2}, dry matter accumulation, LAI and CGR were recorded with the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}(W_1) which was at par with the treatment Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}(W_2) followed by two hand weedings (W_4) and Bispyribac sodium @ 25 g a.i. ha^{-1}(W_3). This may be due to lower dry weight of weed in Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}applied plots followed by Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}, which resulted in less crop-weed competition. Furthermore, increased infestation of weeds showed negative influence on the crop growth as reflected in terms of lower initial plant height and plant biomass due to poor resource utilization (like nutrients uptake) at the critical period of crop-weed competition period *i.e*. 15-60 DAS **.** The possible reason of the maximum plant height in these treatments might be due to congenial and longer weed free environment during crop growth period provided better opportunity for overall growth and development of rice plants lead to maximum plant height. **Kumar *et al.*(2018)** noted thatManual weeding thrice (20, 40 and 60 days) and Pretilachlor @ 750gha^{-1} at 0-2DASfb Almix @ 4 g ha^{-1} at 25DAS (3-4 Leaf stage of rice crop) recorded significantly higher growth parameters as compared to bispyribac-Na @ 25g ha^{-1} at 30 days stage alone and weedy check.This is in accordance with finding of**Kalaisudarsonand Srinivasaperumal (2019) and Suganthi*et al*. (2010).**However, in general, all the plots where herbicides, cultural and mechanical (alone or with herbicide) method applied to control weeds accumulated the higher dry matter of rice than un-weeded control. The possible reason of higher accumulation of dry matter of rice was the effect of herbicides on weeds so rice plant received more space, moisture, light and nutrient for their proper growth and this favored the higher dry matter accumulation of rice per unit area. The higher dry matter accumulation also associated with the higher height and number of tillers m^{-2}. The increasing foliage might have enhanced the photosynthesis due to which plant dry matter accumulation was higher under these treatments.

5.2.2 Effect on weed density, dry matter accumulation of weeds and weed control efficiency

The total weed density, individual density of *Echinochloa crusgalli*, *Cyprus rotundus*, *Eclipta indica*,*Eleusine indica*, *Phyllanthus niruri* and other weeds and their dry weights are given in Table (4.2 and 4.9), (4.3 and 4.10), (4.4 and 4.11), (4.5 and 4.12), (4.6 and 4.13), (4.7 and 4.14), (4.8 and 4.15)shows that the weed growth was slightly more as crop growth start towards development during crop season.This higher growth might be due to more favorable weather condition prevailed like rainfall, sunshine hours, and temperature. Among the crop establishment methods the minimum total weed density and total dry weight were recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum total weed densityand total dry weight were recorded with unpuddled flat method (E_2) except in broad leaf weeds because the maximum density of broad leaf weeds was found in furrowirrigated raised bed method (E_3), it may be due to beds. At harvest the percent reduction in total weed density under conventional puddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flat method (E_2) were to 9.81 and 9.60, 17.44 and 14.55 during experimentation, respectively.**Bhardwaj *et al.* (2018)**noted that conventionally puddled transplanted rice had significantly lower weed density (29.4%) then rest of establishment methods.This is in accordance with finding of**Singh *et al.* (2005).**

The different weed managements practices control the weeds effectively as compared to unweeded check. Significantly the lowest total weed population and total dry weight recorded under two hand weeding treatment because two hand weeding treatment was kept of weeds free by hand weeding. The highest total weed density and dry weight were recorded in weedy check plots due to unchecked growth of weeds, which compete for all the resources up to maturity with crop.The density of narrow leaved and broad-leaved weed was found to be significantly higher in weedy plots at 30, 60, 90 DAT stage and at harvest as compared to other weed management practices. Among the herbicides, density of narrow, broad and other weeds recorded significantly lower in Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} treated plots.Among weed control treatments significantly higher weed dry weight 49.93, & 52.71; 140.89 & 144.20; 148.89 & 152.39; 121.68 & 124.95 g m^{-2}were found in weedy checkat 30, 60, 90 DAT stage and at harvest during both the years of study, respectively.While the lowest dry weight 4.59 & 7.37; 28.88 & 32.19; 31.09 & 34.60; 25.09 & 28.04 g m^{-2} in two hand weeding plots. Among the herbicides lower weed dry weight 6.62 & 9.40; 32.18 & 35.49; 34.53 & 38.03; 27.90 & 30.86 gm^{-2} were found at 30, 60, 90 DAT stage and at harvest with the application of Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}which was at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}. The data on total weed density and their dry weight as affected by different treatments indicated that In general, weed population increased up to 60 DAT, and thereafter showed decreasing trend according to their life cycle. This was due to the fact that at later stage most of the weed growth ceased because of leaf senescence, and thereby resulted in reduction in dry matter accumulation of weeds.**Yadav *et al.* (2017)**also noted that maximum reduction in weed density and dry matter accumulation was recorded with pre-emergence application of Pretilachlor 750 g ha^{-1} fb post emergence application of Bispyribac-Na 20 g ha^{-1} and post-emergence application of Bispyribac-Na 20 g ha^{-1} at 60 DAT was most effective in controlling mixed population of the weed flora. Their effectiveness was at par with twice hand weeding. Similar findings were reported by**Mishra and Singh (2007)andSangeetha*et al.* (2009).**Higher infestation of weeds under weedy check was also reported by **Singh *et al*. (2016)**.

Among the herbicides the highest weed control efficiency (80.36 & 75.67%; 77.16 & 75.65%) was observed in Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}, which was found at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}at 60 & 90 DAT. The Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} showed highest WCE among herbicidal treatments, owing to better control of grasses, sedges and broad leaf weeds by these herbicides. This result is in corroboration with the findings of **Singh *et al.* (2013).** The persistent of bispyribac-sodium is low to moderate in un-puddled field (DSR) whereas it shows moderately higher persistent in flooded paddy soils **Knezevic *et al*. (2017).** This indicates the capability of bispyribac-sodium (BPS) to control weeds for longer periods in transplanted rice than dry direct seeded rice.

5.3 Effect on yield attributes and yields of rice

The expression of grain yield is a function of two parameters i.e., genetic potential and the environmental surrounding of the crop. In order to get maximum yield from a crop of a particular genetic set up various agronomic manipulations can be done. The grain, straw and biological yield was slightly higher in 2020 than 2019 was may be because of comparatively better weather conditions like rainfall, temperature and sunshine hours prevailed during the crop season (Fig.3.1a & 3.1b). The significant increase in grain, straw and biological yield and yield attributes increased with crop establishment methods. Conventional puddled transplanted rice and furrow irrigated raised beds fulfilled the timely crop water and nutrient requirement, and its beneficial effect onthe per plant yield which resulted into better growth in term of dry matter accumulation (Table 4.23).The higher growth finally resulted into significant increase in grain yield might be attributed to significantly higher panicle length, number of effective tillers, number of grains per panicle and test weight. Transplanted rice onconventional puddled transplanted rice and furrow irrigated raised beds increased the grain yield of rice by about (17.10 and 15.85), (13.35 and 9.41) % during both the year of experimentation, respectively (Table 4.23). This increase was because of increased the number of grains per panicle to the tune of (3.5 and 8.9), (5.3 and 3.4) % during the years of study. Similarly, the increase in test weight was also recorded in the range of (7.7

and 9.10), (5.0 and 5.3) % during experimentation, respectively. Present investigation is in conformity with the findings of **Javaid *et al.* (2012)**;**Naresh *et al.* (2014)** and**Rahman *et al.*(2019)**.

Number of grain per panicle, effective tillers m^{-2} and test weight, were significantly influenced due to various weed management practices. Treatment Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} was found superior as compared to all other weed management plots and at par with the treatment of Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}. The yield attributes are decided by genetic makeup of the crop and variety, but the agronomic manipulation also affects them to a great extent. The reproductive growth depends on vegetative growth of plant. More vegetative growth increases the photosynthetic area and supply of photosynthetic toward sink which decides the yield attributes and ultimatelythe yield. The higher values of yield attributes were due to increased synthesis and translocation of metabolites for the panicle development and grain formation. Besides, thousand grain weights were also maintained because of high mobilization of photo-synthesis from source to sink. However, this is quite possible because these combinations of herbicides might have been very effective to reduce the mixed weeds density and their growth resulting in better and congenial environment favoring the rice plant to utilize nutrients, light, space luxuriantly and grew well to produce more number of tillers m^{-2},number of grain $panicle^{-1}$ and test weight, grain and straw yields. Similar finding were reported by **Chaudhary (2020).** The final yield of the crop was the cumulative effect of yield attributes which directly affects and/or indirectly influenced them. A crop can performed best only when the display of foliage on the ground surface was in such a manner that utilizes maximum natural resources.

In our study, grain yield ha^{-1} was significantly influenced by the different weed management practices.Treatment Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} was superior in grain yield ha^{-1}which was at par with Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} and Two hand weeding followed byBispyribac sodium @ 25 g a.i. ha^{-1}, whereas the minimum grain yield ha^{-1} was recorded in weedy check.This might be due to the higher crop growth of rice in terms of foliage, large amount of photosynthesis, which act as source and helped in developing yield attributes due to low crop weed competition and finally the higher grain yield was obtained with the application of pre and post emergence herbicide, resulted in the highest grain yield.Similar findings were reported by**Suganthi*et al*. (2010)**

Higher straw yield was due to more accumulation of dry matter (g m^{-2})along with the highest plant height and number of tillers m^{-2}. The application of Pretilachlor @ 0.75 Kg ha^{-1}fb Bispyribac sodium @ 20 g a.i. ha^{-1} was recorded straw yield (79.63 & 82.40 q ha^{-1}) which was (49.23%) higher as compared to weedy check plots. similar findings were reported by ***Prasadet al. (2001) and Sabhajeet et al. (2020).***

5.4 Effect on NPK content and uptake by crop

The nitrogen content in rice grain, straw, potassium content in grain and NPK uptake in rice grain and straw was significantly influenced with crop establishment methods while, the phosphorus content in rice grains and straw and potassium content in rice straw was non significantly influenced with crop establishment methodsduring both the years of experimentation. The maximum NPK, content (1.11 and 1.13), (0.35 and 0.39) and (0.44 and 0.47) in rice grain, (0.46 and 0.45), (0.17 and 0.18) and (1.33 and 1.42) in rice straw was recorded under furrow irrigated raised bed method (E_3) followed byE_1 and E_2. While, the maximum uptake of NPK (49.80 and 51.57),(15.60 and 17.57) and (19.72 and 21.97) in rice grain, (33.02 and 34.33), (13.00 and 13.52) and (101.07 and 109.87) in rice straw and total uptake were recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3). However, the lowest NPK content in grain and straw and the lowest NPK uptake in grain and straw were found under unpuddled flat method (E_2) during both the years of experimentation. The higher N and P uptake in grain because of its chemical composition due to higher amino acid and protein content in grain require more N and P, whereas, higher K content in straw is because of its higher content is required for providing strength to stem by forming cellulose, lignin and pectin. The higher NPK uptake was mainly because of higher grain and straw yield in E_1 followed by E_3 compared to E_2 during experimentation. Similar trend have been observed by **Bhuyan *et al.* (2012); Naresh *et al.* (2014) and Tyagi *et al*., (2017).**

Among the application of herbicides, the highest content and uptake of nitrogen, phosphorus and potassium was observed with the application of Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} which was found at par with the application of Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}.This was perhaps due to more dry matter production by crop and less nutrient (N, P and K) depletion by weeds and subsequently more availability of these nutrients to crop. Pretilachlor *fb* Bispyribac sodium reduced the uptake of nutrient by weeds and increased by crop which resulted in higher grain and straw yield and it significantly superior over rest of the treatments in rice crop **Barla *et al.* (2021).**

A cursory glance at the data reveals that the highest total nitrogen, phosphorus and potassium uptake (94.80 and 99.84, 31.80 and 34.60, 134.03 and 145.90 kg ha^{-1}) by crop was recorded with the application of Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1},which was at par with the application of the Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} (88.36 and 91.70, 29.63 and 32.90, 128.33 and 138.23 kg ha^{-1}) followed by two hand weeding and Bispyribac sodium @ 25 g a.i. ha^{-1}.The lowest total nitrogen, phosphorus and potassium uptake (44.89 and 46.32, 17.69 and 19.65, 70.11 and 83.43 kg ha^{-1}) was recorded in weedy check. Because there was a marked reduction in growth, yield attributes, yield and nutrient uptake of rice in weedy check despite the adequate availability of nutrient as in case of other treatments. Hence, it appears that crop weed competition under high weed intensity exerted more adverse effect on uptake and utilization of nutrient by crop and weeds to the expected level. With intense competition between weeds and crop for nutrient both resulted in low utilization of nutrients. These findings confirm the results by**Talla and Jena (2014); Naz and Roy (2020).**

5.5 NPK content and uptake by weeds

The NPK content in weeds was non significantly influenced with crop establishment methodsduring both the years of experimentation. The crop establishment methods increased the NPK uptake by the weeds with decrease in nutrient availability during both the years of study. The higher NPK uptake was mainly because of higher weed dry matter accumulation in UPF (E_2)followed by $FIRB_S$ (E_3) compared to CPT (E_1) during both the years of experimentation. Similar trend have been observed by **Barla *et al.* (2021); Kumar *et al.* (2017); Bhardwaj *et al.* (2018).**

Among weed control treatments significantly higher nitrogen, phosphorus and potassium content in weeds 1.10 and 1.12, 0.23 and 0.25,1.29 and 1.31 % was found in weedy check in both the years respectively. Among the herbicides, lower nitrogen, phosphorus and potassium content in weeds at harvest stages was found 0.94 and 0.96, 0.17 and 0.19, 1.06 and 1.09 % with the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}, which was found at par 0.96 and 0.98, 0.18 and 0.20, 1.09 and 1.12 % with the application of Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} as compared to weedy check. The results revealed that application of Pretilachlor *fb* Bispyribac sodium and Almix significantly reduced the N and P uptake of weeds and improved the nutrient uptake of the crop **Singh *et al.* (2017)** and **Geeta Kumari (2015)** also reported similar results.

Depletion of nutrients by weeds invariably resulted in reduced availability of nutrients to the crop and thus brought about marked reduction in crop growth and yield. Significantly more depletion of nutrients (N, P and K) was observed in weedy check as compared to all other treatments. Nitrogen, phosphorus and potassium uptake differ significantly with various treatments involving weed management practices. The highest N uptake by weeds 13.50 and 14.11 kg ha^{-1} was found under weedy check while, the lowest2.41 and 2.76 kg ha^{-1} in two hand weeding in both the year, respectively. Significantly higher P and K uptake 2.92 and 3.25, 15.78 and 16.44 kg ha^{-1},respectively in both the years by weeds were found in weedy check while the lowest phosphorus and potassium uptake 0.50 and 0.59, 2.95 and 3.36 kg ha^{-1},respectively was found in two hand weeding. However lowest depletion of nutrients was observed in Pretilachlor @ 0.75Kgha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}, due to minimum weed dry matter production in the treatment. **Ali *et al.* (2018), Murthy *et al*. (2021), Arthanari*et al.* (2017)** also reported higher uptake of N, P and K by weeds under uncontrolled condition.

5.6 Effect on Soil properties

The soil properties in terms of bulk density, electrical conductivity, pHwere affected by different crop establishment methods after harvesting of rice during both the years of study. The mean value of BD for conventional puddled transplanted rice and unpuddled flat transplanted rice plots were 1.68 and 1.62 Mg m^{-3}, respectively. The BD of furrow irrigated raised beds (E_3) was found to be lower than that of conventional puddled transplanted rice (E_1) during experimentation. The low BD indicated the good physical conditions of furrow irrigated raised beds. Soil reaction is an indication of nature of soils whether it is acidic, neutral, or saline/ alkaline and controls the nutrient availability to the plants. Furrow irrigated raised beds (E_3) and unpuddled flat transplanted rice (E_2) recorded lowest soil Ph and EC while highest Ph and electrical conductivity was recorded under conventional puddled transplanted rice (E_1) plots during both the years. Higher soil pH may be due to the presence of $CaCO_3$ and high contents of bases, especially calcium and magnesium, in the profile. Similar result has been reported by **Jat *et al.* (2009); Gangwar and Singh (2010); Naresh *et al.* (2015)**.

5.7 Effect on economics

Slightly higher gross income, net profit and B: C ratio recorded was during 2020 than 2019 because of comparatively higher grain productivity of rice grain with very less inflection cost of cultivation during both the years. Different crop establishment practices increased the cost of cultivation, gross income, net profit and B:C ratio because of more increase in grain yield and gross income incomparison to increase in cost of cultivation. Among the different crop establishment methods, the highest cost of cultivation and gross return were recorded under conventional puddled transplanted rice (E_1) while, the highest net profit and B: C ratio were recorded under furrow irrigated raised bed method (E_3). This may be because of higher efficiency of systems than other establishment methods. Similar trend has been observed by **Hussain *et al.* (2013) and Gupta and Sayre (2007).**

Among weed management practices the highest cost of cultivation (Rs. 38557 and 39663 ha^{-1}) was recorded under two hands weeding treatment due to higher labor charge and lowest cost of cultivation (Rs. 31277 and 32383 ha^{-1}) was observed in weedy check treatment.**Singh *et al.* (2016); Sharma *et al.* (2020)** and**Pasha *et al.* (2012)** also reported similar results. Moreover, among herbicides treatment, the higher gross returns (Rs. 132726 and 138540 ha^{-1}) and net returns (Rs. 99259 and 103968 ha^{-1}) were recorded in Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}, which was found statistically at par with the application of Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} i.e., gross returns (Rs. 129716 and 133343 ha^{-1}) and net returns (Rs. 96891 and 99414 ha^{-1}). The lowest gross returns (Rs. 81164 and 86171 ha^{-1}) observed in weedy check during both the years, respectively. These findings are in close agreement with the results of**Nivetha*et al.* (2017**) **Suria *et al.* (2011),Dahiphale *et al.* (2015) and Dash *et al.* (2016).**

Among herbicides treatment, the higher B: C Ratio (3.96 and 4.00) was recorded in Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}, which was found statistically at par with the application of Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} i.e., (3.94 and 3.92). The lowest B: C ratio observed in weedy check treatment(2.59 and 2.65) during both the years, respectively.**Marasini*et al.* (2020)** and **Mondal *et al.* (2018)**also reported similar results.

CHAPTER – 6 SUMMARIES AND CONCLUSION

The investigation "Effect of crop establishment methods and weed management options on weed dynamics and performance of Basmati rice (*Oryza sativa* L.)" was carried out at the Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut - 250110 (U.P.) India during *kharif* season of 2019 and 2020 with the following objectives:

- To find out the suitable crop establishment method and weed management options for basmati rice
- To access the weed dynamics and performance of basmati rice under different crop establishment methods and weed management options
- To estimate the nutrient removal by weed and NPK uptake by crop
- Economic feasibility of the treatments.

To fulfill the above objectives, experiment was laid out in split plot design with four replications. Main factors consist of the crop establishment methods *viz.* (1) Conventional Puddled Transplanting (CPT), (2) Unpuddled Flat (UPF) and (3) Furrow Irrigated Raised Beds (FIRB) and the sub factors consist of five weed management options *viz.*, (1) Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} PoE at 20 DAT, (2) Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} PoE at 20 DAT, (3) Bispyribac sodium @ 25 g a.i. ha^{-1} PoE at 20 DAT, (4) Two hand weedings and (5) Weedy check. The salient findings during course of investigation have been summarized in this chapter as follows:

Effect of crop establishment methods

- The crop performed better during second over first season due to weather being more favorable for growth and development of crop, so resulting higher yield during second year of experimentation.

- The minimum total weed density was recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum total weed density was recorded with unpuddled flat method (E_2) during both the years. The percent reduction in total weed density under conventional puddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flat method (E_2) was to 9.81 and 9.60, 17.44 and 14.55 percent during 2019 and 2020, respectively.
- The minimum density of *Echinochloa crusgalli* (L) , *Cyprus rotundus* (L), *Eclipta alba* , *Eleusine indica*, *Phyllanthus niruri* and other weedswas recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum density of these weedswas recorded with unpuddled flat method (E_2) during both the years. The percent reduction under conventional puddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flat method (E_2) was to the tune of 4.88, 2.64; 25.12, 17.66; 1.62, 7.62; 18.58, 17.42; 17.52, 15.74; 9.17, 7.85; 7.12, 5.54; 17.17, 15.80; 23.91, 18.23; 9.96, 4.82; 15.10, 13.07; 4.95, 7.62; percent during 2019 and 2020, respectively.
- The minimum dry weight of total weedswas recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the maximum dry weight of total weeds was recorded with unpuddled flat method (E_2) during both the years. The percent reduction in dry weight of total weedsunder conventional puddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flat method (E_2) was to 23.08, 21.18 and 25.35, 23.34 percent during 2019 and 2020, respectively.
- The minimum dry weight of *Echinochloa crusgalli* (L), *Cyprus rotundus* (L), *Eclipta alba*, *Eleusine indica*, *Phyllanthus niruri* and other weeds was recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the

maximum dry weight of *Echinochloa crusgalli* (L) was recorded with unpuddled flat method (E_2) during both the years. The percent reduction in dry weight ofthese weedsunder conventional puddled transplanting (E_1) compared to furrow irrigated raised bed (E_3) and unpuddled flat method (E_2) was to the tune of 18.08, 15.95; 26.49, 24.28; 19.72, 18.44; 26.38, 25.06; 33.23, 31.00; 20.33, 18.21; 14.71, 13.87; 25.65, 23.93; 26.68, 25.24; 15.89, 14.77; 16.17, 14.74; 24.85, 22.89 percent during 2019 and 2020, respectively.

- The maximum weed control efficiency at 60 and 90 days was found (61.34, 57.74 and 59.42, 57.80 %) under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the minimum weed control efficiency was found (56.66, 52.55 and 53.25, 52.14 %) with unpuddled flat method (E_2) during 2019 and 2020, respectively.
- The maximum plant height was recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the minimum plant height was recorded under unpuddled flat (E_2) method during both the years.
- The number of tillers m^{-2} also influenced significantly under different crop establishment methods during both the years. The maximum number of tillers was recorded under furrow irrigated raised bed method (E_3) which was at par with conventional puddled transplanting (E_1) while the minimum number of tillers was recorded under unpuddled flat method (E_2) during both the years.
- Significantly higher dry matter accumulation was recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the minimum dry matter accumulationwas recorded under unpuddled flat (E_2) method during both the years.

- The maximum LAI and CGR was calculated under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3) while the minimum LAI and CGR was calculated under unpuddled flat method (E_2) during both the years.
- The yield attributing characters *viz*. effective tillers (m^2), panicle length (cm), no. of grain panicle^{-1} was significantly influenced while; the 1000-grain weight (g) was non significantly influenced by crop establishment methods during both the years. Effective tillers m^{-2} was significantly higher in conventional puddled transplanted basmati rice which was at par with furrow irrigated raised beds method. Yield attributes *viz*., panicle length and 1000 grain weight were statistically at par among different methods of establishment but grains panicle^{-1} was significantly higher under conventional puddled transplanted basmati rice over unpuddled transplanting while, it was statistically at par with furrow irrigated raised bed method.
- Significantly the highest grain, straw and biological yield (44.91 and 46.26 q ha^{-1}), (76.40 and 77.74 q ha^{-1}), (121.31 and 124.00 q ha^{-1}) recorded under conventional puddled transplanting (E_1) which was significantly higher than the unpuddled flat (E_2) (37.23 and 39.93 q ha^{-1}), (65.10 and 70.30 q ha^{-1}), (102.33 and 110.23 q ha^{-1}) and at par with furrow irrigated raised bed method (E_3) (42.97 and 44.08 q ha^{-1}), (73.22 and 73.82 q ha^{-1}) , (116.19 and 117.90 q ha^{-1}) in the year 2019 and 2020, respectively.
- Harvest index was non significantly influenced by crop establishment methods. The highest harvest index (36.90 and 37.17 %) recorded under conventional puddled transplanting (E_1) which was higher than the furrow irrigated raised bed method (E_3) and unpuddled flat (E_2) in both the year, respectively.
- The N, P and K content in weeds was non significantly affected with crop establishment methods during both the years. The maximum N, P and K contents in weeds was (1.024,

0.206, 1.195 and 1.044, 0.226, 1.219) recorded under unpuddled flat method (E_2) followed by furrow irrigated raised bed method (E_3). However, the lowest N, P and K content (0.99, 0.200, 1.164 and 1.010, 0.219, 1.194) was found under conventional puddled transplanting (E_1) method during 2019 and 2020, respectively.

- The N, P and K removal by weeds under conventional puddled transplanting method (E_1) (4.09, 0.84, 5.08 and 4.48, 1.01, 5.56 kg ha^{-1}) was significantly lowest then rest of the treatments during both the years. However, the highest N, P and K removal by weeds (7.13, 1.44, 8.03 and 7.59, 1.65, 8.52 kg ha^{-1}) was obtained under unpuddled flat method (E_2) during 2019 and 2020, respectively.
- The N and k content in rice grain, straw and N, P, K uptake in rice grain and straw was significantly influenced with crop establishment methods during both the years. While phosphorous content was non significantly influenced by establishment methods. The maximum N, P and K content in rice grain and straw was recorded under furrow irrigated raised bed method (E_3) and the maximum uptake of N, P and K in rice grain, straw and total uptake were recorded under conventional puddled transplanting (E_1) followed by furrow irrigated raised bed method (E_3). However, the lowest NPK content in grain, straw and lowest NPK uptake in grain and straw was found under unpuddled flat method (E_2) during 2019 and 2020, respectively.
- The highest cost of cultivation, gross return was calculated in conventional Puddled transplanted rice (E_1) while, the highest net return and B: C ratio was calculated in furrow irrigated raised beds (E_3). Whereas, the lowest values calculated in unpuddled flats (E_2) during both the year of study.

Effect of weed management practices

- Weed management practices on total weed density was significant and two hand weedings was found most effective in reducing total weed density as compared to rest of the weed management practices. Among the herbicides, application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) was found most effective in reducing the total weed density at every observation dates.
- The effect of different weed management practices ondensity of *Echinochloa crusgalli* (L), *Cyprus rotundus* (L), *Eclipta alba, Eleusine indica***,** *Phyllanthus niruri* and other weeds was significant and two hand weedings was found most effective in reducing Density of different weeds as compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) was found most effective in reducing the Density ofweedsat every observation dates.
- Two hand weedings (W_4) was found most effective in reducing dry weight of total weedsas compared to rest of the weed management practices. Among the herbicides, application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) was found most effective in reducing the dry weight of total weedsat every observation dates.
- The effect of different weed management practices on dry weight of *Echinochloa crusgalli*(L), *Cyprus rotundus* (L), *Eclipta alba, Eleusine indica***,** *Phyllanthus niruri* and other weeds was significant and two hand weedings (W_4) was found most effective in reducing dry weight ofdifferentweedsas compared to rest of the weed management practices. In herbicides the application of Pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} (W_1) was found most effective in reducing the dry weight ofdifferent weeds at every observation dates.

- The maximum weed control efficiency at 60 and 90 DAS was found in two hand weedings followed by Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} while the minimum weed control efficiency was found with Bispyribac sodium @ 25 g a.i. ha^{-1}.
- Among the herbicides treatments the highest plant height, number of tillers, dry matter accumulation, leaf area index, and Crop growth rate at all the growth stages were recorded under pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} followed by Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} treatment as compared to other treatments. At 60, and 90DAT Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} was recorded best than rest of the treatments.
- Significantly the highest effective tillers, panicle length, number of grains $panicle^{-1}$ and test weight was found with the application of under Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}treatment followed by Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}.
- Among the different weed management treatments the highest grain, straw and biological yield was obtained under Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} which was at par with the application of Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} and two hands weeding.
- Various weed management treatments significantly influenced the nutrient content (%) and uptake (kg ha^{-1}). The highest N, P and K content and uptake by weeds were found in weedy check over rest of the treatments. The lowest uptake of N, P and K by weeds was observed with two hand weeding treatment followed by the Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}.
- Various herbicidal treatments influenced the total N, P and K content (%) and uptake (kg ha^{-1}) of rice grain and straw significantly. The highest total NPK content and uptake by grain

and straw were found by Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}. The lowest total content and uptake of N, P and K by grain and straw was observed with weedy check.

- Among the different weed management treatments, the highest cost of cultivation was found under two hands weeding and highest gross returns, net returns and B: C ratio were recorded by Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1}, which was at par with the application of Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}.

Based on the results of experimentation, it can be concluded that among all the crop establishment methods conventional puddled transplanting (E_1) exhibited significant influence on the growth, yield attributes and yield of basmati rice followed by furrow irrigated raised bed method (E_3) and the lowest growth, yield attributes and yield were found under unpuddled flat method (E_2) during both the years. However, furrow irrigated raised bed method (E_3) has potential to produce slightly lower or comparable yields as that of conventional puddled transplanting (E_1) and appears to be a viable alternative to overcome the problem of labour shortage. FIRB method also showed better effect on number of tillers, yield attributes, soil properties and profitability of Basmati rice.

Among weed management options all the weed control practices proved effective in controlling the weeds in rice and gave significantly higher grain yield over weedy check. Among the different treatments, two manual weeding to keep the plot weed free was the most effective weed control measure to control narrow, broad leaved and sedge weeds and resulted into higher value of weed control efficiency which was statistically at par to Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} and Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}. Highest growth parameters, yield and yield attributes of rice and nutrient uptake was noticed with the application of Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} which was found statistically at par with the Almix 4g a.i. ha^{-1}+ Bispyribac sodium @ 20 g a.i. ha^{-1} and Two hand weeding. Among weed management treatments Pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} was found excellent in gross return, net return, and B: C ratio which was at par with the Almix 4g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}. Thus, the application of pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} seems better for higher productivity and profitability of rice crop**.**

Therefore, furrow irrigated raised bed method with pretilachlor @ 0.75 Kg ha^{-1} *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} weed management option proved to be better. Results of this investigation can be extended to similar soil and climatic condition for wide area.

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APPENDICES

APPENDIX-I

Mean weekly meteorological data during the crop growing season (*Kharif* 2019)

Standard Weeks	Rainfall (mm)	Temperature (^{0}C)		Relative Humidity (%)		Wind velocity (Km/hr.)	BSS (hrs.)
		Max.	Min.	Mor.	Eve.		
24	0.0	41.3	26.7	84.0	60.7	10.0	9.1
25	2.1	39.0	25.4	71.0	44.1	17.6	8.6
26	0.0	41.3	26.4	84.0	60.7	10.0	9.1
27	0	40.1	25.1	84.3	46.6	13.8	7.6
28	92.3	36.1	24.2	90.3	69.3	15.3	3.1
29	8.4	36.4	23.9	87.3	50.6	9.1	8.0
30	150	35.3	24.5	93.7	68.0	12.7	3.0
31	48	35.9	25.2	90.0	46.6	16.5	2.3
32	92	34.0	25.2	94.8	67.6	4.3	3.9
33	64	32.0	24.4	95.0	86.7	2.2	4.6
34	3.2	33.7	24.5	94.8	71.3	1.2	7.4
35	88	34.8	25.2	93.3	70.7	0.7	8.7
36	0	34.4	25.4	95.8	76.0	0.7	6.7
37	0	34.5	25.0	94.8	71.4	0.5	7.3
38	2.3	33.5	23.2	93.7	62.4	0.7	8.5
39	14.4	31.4	22.6	94.8	72.3	0.9	6.0
40	22.9	31.2	20.6	95.2	60.7	1.1	8.0
41	0	31.9	18.9	93.5	57.0	0.8	8.6
42	0	32.0	18.5	94.7	61.0	0.6	6.7
43	0	30.1	15.9	94.2	50.9	1.2	6.9
44	0	29.8	15.8	93.7	53.7	0.6	7.8

APPENDIX-II

Mean weekly meteorological data during the crop growing season (*Kharif* 2020)

Standard Weeks	Rainfall (mm)	Temperature (^{0}C)		Relative Humidity (%)		Wind velocity (Km/hr.)	BSS (hrs.)
		Max.	Min.	Mor.	Eve.		
24	0.2	38.1	27.0	69.3	50.7	5.2	9.7
25	1.1	35.4	26.6	79.0	55.6	3.0	8.8
26	7.2	36.1	27.3	73.9	60.3	4.4	8.2

27	30.3	35.4	26.1	78.7	66.1	4.6	7.1
28	150.4	32.5	24.6	88.1	73.7	4.0	2.7
29	23	33.5	25.9	82.9	71.4	4.4	7.1
30	19.1	33.5	25.9	86.3	72.6	4.4	5.7
31	12.1	34.9	26.4	82.7	72.1	4.2	3.9
32	61.5	32.2	24.7	93.3	84.0	1.9	1.7
33	55.3	32.1	25.0	81.6	69.1	4.8	6.6
34	0.2	33.4	25.0	83.9	72.3	4.5	7.1
35	4.3	34.3	26.3	77.3	61.7	3.1	7.6
36	5.1	35.6	26.6	78.0	59.0	1.3	7.4
37	0.0	36.4	27.1	78.4	53.9	2.7	8.8
38	0.0	36.0	26.2	80.1	55.0	2.2	8.4
39	0.0	33.8	22.1	80.1	56.4	2.2	8.8
40	0.0	35.2	20.7	84.0	52.1	1.8	8.7
41	0.0	33.7	19.0	86.7	48.0	1.7	8.3
42	0.0	33.0	16.1	85.4	45.1	1.7	7.6
43	0.0	33.0	16.1	85.4	45.1	1.7	7.6
44	0.0	31.0	13.4	81.6	43.7	1.1	7.5

APPENDIX-III

Analysis of variance for total weed density at different stages

Source of variation	d.f.	Mean sum of square for total weed density							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.04	0.04	0.08	0.09	0.05	0.06	0.03	0.03
Establishment methods (E)	2	39.27*	34.75*	22.85*	20.12*	15.79*	12.23*	13.61*	10.12*
Error (a)	6	0.52	0.58	0.99	1.07	0.91	0.98	0.59	0.65
Weed management options (W)	4	191.54*	179.51*	172.65*	171.51*	181.83*	175.4*6	149.59*	142.96*
Interaction (E×W)	8	0.18	0.19	0.22	0.08	0.20	0.07	0.10	0.05
Error (b)	36	0.29	0.32	0.54	0.55	0.40	0.41	0.30	0.31

APPENDIX-IV

Analysis of variance for *Echinochloa crusgalli* (L) density at different stages

Source of	d.f.	Mean sum of square for *Echinochloa crusgalli* (L)

variation		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.06	0.009	0.011	0.011	0.016	0.017	0.014	0.011
Establishment methods (E)	2	8.94*	8.14*	4.402*	3.967*	5.724*	3.641*	5.629*	2.988*
Error (a)	6	0.17	0.09	0.152	0.164	0.114	0.136	0.076	0.089
Weed management options (W)	4	30.23*	28.82*	25.931*	25.706*	31.055*	24.646*	27.091*	20.098*
Interaction (E×W)	8	0.16	0.16	0.101	0.086	0.171	0.085	0.091	0.070
Error (b)	36	0.14	0.07	0.083	0.086	0.098	0.086	0.069	0.070

APPENDIX-V

Analysis of variance for *Cyprus rotundus*(L) density at different stages

Source of variation	d.f.	Mean sum of square for *Cyprus rotundus*(L)							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.029	0.029	0.024	0.024	0.019	0.014	0.015	0.015
Establishment methods (E)	2	8.080*	6.711*	9.815*	7.420*	7.182*	5.321*	5.801*	4.302**
Error (a)	6	0.141	0.147	0.278	0.280	0.194	0.215	0.214	0.230
Weed management options (W)	4	66.163*	65.070*	54.815*	52.363*	56.219*	53.481*	45.783*	43.559*
Interaction (E×W)	8	0.109	0.096	0.482	0.204	0.325	0.178	0.271	0.146
Error (b)	36	0.105	0.104	0.215	0.153	0.162	0.138	0.141	0.121

APPENDIX-VI

Analysis of variance for *Eclipta alba* density at different stages

Source of variation	d.f.	Mean sum of square for *Eclipta alba* density							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.005	0.016	0.004	0.006	0.003	0.003	0.003	0.004
Establishment methods (E)	2	3.313*	2.425*	4.073*	2.317*	2.532*	2.174*	1.848*	1.599*
Error (a)	6	0.094	0.121	0.137	0.152	0.127	0.140	0.085	0.093
Weed management options (W)	4	16.761*	16.434*	16.241*	16.791*	21.558*	21.237*	15.355*	15.149*

Interaction (E×W)	8	0.085	0.119	0.054	0.073	0.200	0.137	0.132	0.090
Error (b)	36	0.067	0.088	0.093	0.107	0.100	0.091	0.072	0.066

APPENDIX-VII

Analysis of variance for *Eleusine indica* density at different stages

Source of variation	d.f.	Mean sum of square for *Eleusine indica* density							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.005	0.005	0.015	0.017	0.012	0.013	0.007	0.008
Establishment methods (E)	2	17.020*	13.831*	4.302*	4.169*	2.735*	2.577*	2.323*	2.192*
Error (a)	6	0.088	0.099	0.156	0.170	0.145	0.156	0.087	0.096
Weed management options (W)	4	28.598*	26.053*	27.020*	26.884*	24.240*	23.748*	20.555*	20.153*
Interaction (E×W)	8	0.143	0.130	0.072	0.087	0.191	0.122	0.160	0.102
Error (b)	36	0.069	0.070	0.078	0.087	0.099	0.089	0.074	0.065

APPENDIX-VIII

Analysis of variance for *Phyllanthus niruri* density at different stages

Source of variation	d.f.	Mean sum of square for *Phyllanthus niruri* density							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.003	0.004	0.003	0.002	0.001	0.002	0.003	0.003
Establishment methods (E)	2	5.620*	4.447*	4.433*	2.512*	4.933*	2.512*	4.006*	2.400*
Error (a)	6	0.088	0.098	0.122	0.088	0.093	0.088	0.087	0.084
Weed management options (W)	4	24.270*	22.383*	18.366*	25.691*	22.216*	25.691*	18.026*	21.199*
Interaction (E×W)	8	0.130	0.125	0.126	0.130	0.061	0.130	0.049	0.054
Error (b)	36	0.067	0.069	0.086	0.078	0.062	0.078	0.059	0.062

APPENDIX-IX

Analysis of variance for other weeds density at different stages

Source of variation	d.f.	Mean sum of square for other weed density							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.012	0.010	0.008	0.010	0.007	0.005	0.010	0.008
Establishment methods (E)	2	4.126*	5.065*	4.194*	5.885*	2.171*	1.573*	1.767*	1.280*
Error (a)	6	0.117	0.136	0.131	0.147	0.146	0.158	0.108	0.116
Weed management options (W)	4	24.915*	22.781*	30.411*	31.531*	25.256*	24.724*	20.545*	20.122*
Interaction (E×W)	8	0.089	0.091	0.133	0.157	0.216	0.220	0.177	0.178
Error (b)	36	0.067	0.073	0.087	0.098	0.107	0.110	0.092	0.096

APPENDIX-X

Analysis of variance for total dry weight at different stages

Source of variation	d.f.	Mean sum of square for total dry weight							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.010	0.011	0.022	0.024	0.014	0.015	0.018	0.018
Establishment methods (E)	2	6.698*	5.545*	26.969*	24.157*	28.161*	25.294*	23.361*	20.998*
Error (a)	6	0.173	0.195	0.631	0.660	0.531	0.560	0.533	0.560
Weed management options (W)	4	44.865*	39.540*	98.889*	93.122*	103.002*	97.100*	84.878*	80.221*
Interaction (E×W)	8	0.240	0.240	1.558	1.234	1.547	1.233	1.322	1.055
Error (b)	36	0.123	0.130	0.588	0.526	0.575	0.517	0.496	0.446

APPENDIX-XI

Analysis of variance for *Echinocloa crusgalli* (L) dry weight at different stages

Source of variation	d.f.	Mean sum of square for *Echinocloa crusgalli* (L)dry weight							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.002	0.002	0.005	0.006	0.003	0.003	0.004	0.004
Establishment methods (E)	2	1.109*	0.929*	3.471*	3.064*	3.722*	3.328*	3.252*	2.874*
Error (a)	6	0.031	0.036	0.066	0.072	0.069	0.075	0.067	0.072

Weed management options (W)	4	9.254*	8.107*	10.128*	9.317*	11.139*	10.307*	9.526*	8.768*
Interaction (E×W)	8	0.193	0.180	0.255	0.212	0.263	0.224	0.237	0.197
Error (b)	36	0.058	0.057	0.087	0.079	0.087	0.081	0.079	0.072

APPENDIX-XII

Analysis of variance for *Cyprus rotundus* (L) dry weight at different stages

Source of variation	**d.f.**	**Mean sum of square for *Cyprus rotundus* (L) dry weight**							
		30 DAT		**60 DAT**		**90 DAT**		**At harvest**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	3	0.002	0.002	0.006	0.006	0.007	0.007	0.007	0.007
Establishment methods (E)	2	1.180*	1.078*	6.644*	6.059*	7.122*	6.550*	5.747*	5.365*
Error (a)	6	0.031	0.033	0.096	0.101	0.154	0.160	0.119	0.125
Weed management options (W)	4	9.031*	8.499*	25.658*	24.562*	28.523*	27.378*	23.221*	22.586*
Interaction (E×W)	8	0.138	0.135	0.732	0.645	0.774	0.693	0.621	0.565
Error (b)	36	0.044	0.044	0.203	0.185	0.230	0.213	0.183	0.173

APPENDIX-XIII

Analysis of variance for *Eclipta alba* dry weight at different stages

Source of variation	**d.f.**	**Mean sum of square for *Eclipta alba* dry weight**							
		30 DAT		**60 DAT**		**90 DAT**		**At harvest**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	3	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Establishment methods (E)	2	1.061*	1.083*	7.050*	6.389*	8.472*	7.647*	6.755*	6.126*
Error (a)	6	0.016	0.017	0.076	0.079	0.096	0.101	0.063	0.067
Weed management options (W)	4	4.496*	4.434*	13.220*	12.403*	15.760*	14.756*	12.710*	11.930*
Interaction (E×W)	8	0.084	0.086	0.556	0.467	0.677	0.563	0.530	0.446
Error (b)	36	0.028	0.028	0.163	0.145	0.189	0.165	0.159	0.142

APPENDIX-XIV

Analysis of variance for *Eleusine indica* dry weight at different stages

Source of variation	d.f.	Mean sum of square for *Eleusine indica* dry weight							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.001	0.001	0.008	0.007	0.008	0.008	0.005	0.005
Establishment methods (E)	2	1.872*	1.539*	4.085*	3.767*	4.761*	4.387*	3.836*	3.539*
Error (a)	6	0.025	0.028	0.083	0.089	0.079	0.085	0.086	0.091
Weed management options (W)	4	5.254*	4.683*	13.502*	12.691*	15.652*	14.705*	12.707*	11.948*
Interaction (E×W)	8	0.089	0.071	0.231	0.211	0.263	0.240	0.217	0.199
Error (b)	36	0.030	0.027	0.091	0.089	0.107	0.104	0.081	0.078

APPENDIX-XV

Analysis of variance for *Phyllanthus niruri* dry weight at different stages

Source of variation	d.f.	Mean sum of square for *Phyllanthus niruri* dry weight							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Establishment methods (E)	2	0.651*	0.517*	4.423*	4.174*	3.864*	3.639*	3.105*	2.929*
Error (a)	6	0.021	0.026	0.074	0.077	0.074	0.078	0.057	0.060
Weed management options (W)	4	5.467*	4.604*	11.058*	10.583*	9.535*	9.113*	7.696*	7.361*
Interaction (E×W)	8	0.113	0.102	0.393	0.370	0.340	0.319	0.272	0.256
Error (b)	36	0.034	0.033	0.122	0.118	0.104	0.100	0.088	0.085

APPENDIX-XVI

Analysis of variance for other weeds dry weight at different stages

Source of variation	d.f.	Mean sum of square for other weeds dry weight							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.003	0.003	0.009	0.009	0.007	0.007	0.004	0.003

Establishment methods (E)	2	1.310*	1.123*	5.061*	4.580*	4.357*	3.951*	3.515*	3.199*
Error (a)	6	0.018	0.022	0.122	0.128	0.098	0.103	0.069	0.073
Weed management options (W)	4	6.302*	5.522*	23.063*	21.767*	19.982*	18.876*	16.249*	15.372*
Interaction (E×W)	8	0.145	0.143	0.545	0.459	0.460	0.389	0.362	0.308
Error (b)	36	0.044	0.045	0.171	0.154	0.150	0.136	0.111	0.100

APPENDIX-XVII

Analysis of variance for weed control efficiency at 60 and 90 stages

Source of variation	d.f.	Mean sum of square for weed control efficiency			
		60 DAT		90 DAT	
		2019	2020	2019	2020
Replication	3	78.043	34.430	0.004	0.004
Establishment methods (E)	2	437.010*	438.939*	1.766*	1.614*
Error (a)	6	40.012	21.552	0.281	0.275
Weed management options (W)	4	15413.50*	13712.08*	147.352*	143.635*
Interaction (E×W)	8	107.568	100.435	0.332	0.315
Error (b)	36	51.645	38.830	0.245	0.237

APPENDIX-XVIII

Analysis of variance for plant height (cm) at different stages

Source of variation	d.f.	Mean sum of square for plant height							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	68.829	74.256	167.045	172.817	313.023	292.711	319.185	316.658
Establishment methods (E)	2	81.395*	152.446*	293.378*	419.743*	411.389*	470.146*	344.601*	421.936*
Error (a)	6	13.642	15.038	36.248	32.994	61.296	92.236	67.279	70.132
Weed management options (W)	4	74.654*	63.135*	690.363*	744.713*	1171.092*	1118.012*	1146.734*	1173.474*
Interaction (E×W)	8	3.899	7.059	2.572	2.531	4.700	4.100	6.366	11.013
Error (b)	36	8.401	9.681	19.720	20.756	37.264	43.222	37.418	39.670

APPENDIX-XIX

Analysis of variance for number of tillers (m^2) at different stages

Source of variation	d.f.	Mean sum of square for number of tillers (m^2)							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	603.222	607.313	1890.781	1957.847	1716.508	1774.913	1679.587	1706.495
Establishment methods (E)	2	672.157*	754.580*	2053.913*	2629.465*	1977.357*	1994.715*	2120.841*	1962.474*
Error (a)	6	128.710	119.420	392.698	416.975	362.545	406.007	381.828	353.353
Weed management options (W)	4	1490.767*	1553.526*	17595.346*	18236.690*	16259.476*	17505.755*	16598.044*	17235.705*
Interaction (E×W)	8	35.261	24.279	80.625	56.815	77.701	102.597	81.387	110.344
Error (b)	36	74.228	74.638	249.379	249.789	225.950	239.104	223.180	233.954

APPENDIX-XX

Analysis of variance for dry matter accumulation (g m^{-2}) at different stages

Source of variation	d.f.	Mean sum of square for dry matter accumulation (g m^{-2})							
		30 DAT		60 DAT		90 DAT		At harvest	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	597.106	214.697	4330.157	4542.310	10852.266	10391.498	10556.241	11304.588
Establishment methods (E)	2	1401.505*	1733.654*	38139.000*	40751.760*	111464.759*	105943.357*	157633.510*	116878.656*
Error (a)	6	125.402	89.092	1669.814	1698.820	3928.454	3915.832	3900.486	4362.177
Weed management options (W)	4	1904.954*	1850.325*	10266.460*	11213.097*	135223.397*	131846.709*	168722.957*	146839.384*
Interaction (E×W)	8	144.691	86.904	1435.343	1304.149	1578.238	1834.973	284.486	3467.432
Error (b)	36	105.709	87.103	1586.373	1675.504	3532.740	3799.899	3548.743	4163.686

APPENDIX-XXI

Analysis of variance for leaf area index at different stages

Source of variation	d.f.	Mean sum of square for leaf area index		
		30 DAT	60 DAT	90 DAT

		2019	2020	2019	2020	2019	2020
Replication	3	0.058	0.064	0.363	0.320	0.225	0.547
Establishment methods(E)	2	0.153*	0.140*	0.772*	1.387*	0.693*	0.973*
Error (a)	6	0.023	0.023	0.125	0.131	0.090	0.211
Weed management options (W)	4	0.235*	0.235*	8.284*	8.900*	8.460*	8.517*
Interaction (E×W)	8	0.092	0.092	1.467	1.753	1.462	2.149
Error (b)	36	0.038	0.040	0.425	0.497	0.399	0.595

APPENDIX-XXII

Analysis of variance for at different stages Crop Growth Rate (g/m^2/day)

Source of variation	d.f.	Mean sum of square for Crop Growth Rate (g/m^2/day)			
		30- 60 DAT		60-90 DAT	
		2019	2020	2019	2020
Replication	3	10.261	9.961	4.873	3.533
Establishment methods (E)	2	25.731*	28.534*	31.022*	19.390*
Error (a)	6	1.876	1.951	1.227	1.390
Weed management options (W)	4	4.314*	4.955*	81.409*	76.633*
Interaction (E×W)	8	2.381	1.889	2.861	3.937
Error (b)	36	1.638	1.673	1.265	1.603

APPENDIX-XXIII

Analysis of variance for yield attributes

Source of variation	d.f.	Mean sum of square for yield attributes							
		Effective tillers (m^2)		Panicle length(cm)		No. of grain per panicle		1000 grain weight (g)	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	755.312	1094.708	13.947	14.278	543.634	559.530	14.705	14.798
Establishment methods (E)	2	1887.295*	806.560*	23.763*	36.968*	568.944*	548.891*	12.914	13.649
Error (a)	6	288.105	238.849	4.728	4.824	108.129	102.743	2.780	2.827
Weed management options (W)	4	6982.344*	7091.613*	104.753*	87.527*	257.049*	333.971*	12.164*	14.767*

Interaction (E×W)	8	325.801	281.037	2.429	3.505	36.331	36.571	1.921	1.816
Error (b)	36	222.150	192.662	3.149	3.484	66.518	69.773	2.035	2.026

APPENDIX-XXIV

Analysis of variance for grain, straw, biological yield and harvest index

Source of variation	d.f.	Mean sum of square for yield(q ha^{-1})							
		Grain Yield		Straw Yield		Biological yield		Harvest Index	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	44.315	67.043	186.547	195.836	450.929	494.986	51.377	52.380
Establishment methods (E)	2	318.749*	206.813*	679.509*	277.181*	1928.603*	952.459*	3.038	8.649
Error (a)	6	15.855	15.105	41.672	38.238	86.202	108.078	10.240	10.286
Weed management options (W)	4	800.676*	782.724*	1389.402*	1388.558*	4272.644*	4226.779*	27.008*	21.289*
Interaction (E×W)	8	1.348	1.359	4.847	1.290	7.727	4.120	0.884	0.221
Error (b)	36	9.446	8.643	23.147	23.909	58.001	60.749	5.728	5.628

APPENDIX-XXV

Analysis of variance for nutrient content (%) in weeds at harvest

Source of variation	d.f.	Mean sum of square for nutrient content in weeds					
		Nitrogen		Phosphorous		Potassium	
		2019	2020	2019	2020	2019	2020
Replication	3	0.000	0.000	0.000	0.000	0.000	0.000
Establishment methods (E)	2	0.006	0.006	0.000	0.000	0.005	0.003
Error (a)	6	0.001	0.001	0.000	0.000	0.002	0.002
Weed management options (W)	4	0.056*	0.056*	0.007*	0.008*	0.117*	0.111*
Interaction (E×W)	8	0.040	0.040	0.002	0.002	0.003	0.004
Error (b)	36	0.010	0.010	0.000	0.000	0.002	0.002

APPENDIX-XXVI

Analysis of variance for nutrient uptake (kg ha^{-1}) by weeds at harvest

Source of variation	d.f.	Mean sum of square for nutrient uptake by weeds					
		Nitrogen		Phosphorous		Potassium	
		2019	2020	2019	2020	2019	2020
Replication	3	1.800	1.552	0.077	0.100	2.679	3.035
Establishment methods (E)	2	51.454*	53.747*	2.094*	2.323*	52.228*	53.356*
Error (a)	6	0.294	0.372	0.014	0.018	0.604	0.674
Weed management options (W)	4	276.328*	290.090*	13.313*	15.973*	378.680*	395.130*
Interaction (E×W)	8	4.628	4.891	0.288	0.327	1.536	1.703
Error (b)	36	1.377	1.501	0.076	0.088	0.772	0.850

APPENDIX-XXVII

Analysis of variance for nitrogen content (%) and uptake (kg ha^{-1})

Source of variation	d.f.	Mean sum of square for nitrogen content and uptake									
		Nitrogen content (%)				Nitrogen uptake (kg ha^{-1})				Total uptake (kg ha^{-1})	
		Grain		Straw		Grain		Straw			
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.000	0.000	0.000	0.000	49.144	77.866	34.631	35.480	165.488	218.391
Establishment methods (E)	2	0.008*	0.009*	0.011*	0.003*	503.097*	340.732*	238.544*	91.740*	1414.610*	786.070*
Error (a)	6	0.002	0.002	0.000	0.000	35.037	10.883	15.557	4.702	27.958	8.893
Weed management options (W)	4	0.092*	0.092*	0.033*	0.053*	1672.018*	1713.398*	727.334*	932.738*	4582.207*	5152.435*
Interaction (E×W)	8	0.000	0.000	0.002	0.000	4.278	4.347	9.168	0.941	12.163	7.549
Error (b)	36	0.001	0.001	0.001	0.000	16.511	12.674	7.932	5.882	16.851	14.188

APPENDIX-XXVIII

Analysis of variance for phosphorus content (%) and uptake (kg ha^{-1})

Source of variation	d.f.	Mean sum of square for phosphorus content and uptake				
		Phosphorus content (%)		Phosphorus uptake (kg ha^{-1})		Total uptake (kg ha^{-1})
		Grain	Straw	Grain	Straw	

		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.000	0.000	0.000	0.000	4.926	9.452	5.556	5.915	20.852	30.304
Establishment methods (E)	2	0.001	0.001	0.000	0.000	47.337*	37.636*	28.208*	9.827*	148.117*	85.470*
Error (a)	6	0.000	0.000	0.000	0.000	0.965	2.464	1.456	1.610	0.565	3.793
Weed management options (W)	4	0.003*	0.005*	0.001*	0.000	131.274*	170.522*	58.415*	55.163*	363.425*	418.523*
Interaction (E×W)	8	0.001	0.000	0.001	0.001	0.740	0.452	5.122	3.269	5.708	4.614
Error (b)	36	0.000	0.000	0.000	0.000	1.434	1.686	2.134	1.472	3.059	3.134

APPENDIX-XXIX

Analysis of variance for potassium content (%) and uptake (kg ha^{-1})

Source of variation	d.f.	Mean sum of square for Potassium content and uptake									
		Potassium content (%)				Potassium uptake (kg ha^{-1})				Total uptake (kg ha^{-1})	
		Grain		Straw		Grain		Straw			
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	0.000	0.000	0.000	0.000	7.642	14.102	329.455	389.445	436.372	551.734
Establishment methods (E)	2	0.002*	0.003*	0.009	0.007	77.549*	77.198*	1568.887*	785.702*	2342.477*	1354.870*
Error (a)	6	0.000	0.000	0.002	0.003	4.528	3.084	102.254	73.801	89.591	63.177
Weed management options (W)	4	0.095*	0.026*	0.081*	0.049*	479.992*	339.692*	4354.196*	4359.586*	7697.419*	7097.273*
Interaction (E×W)	8	0.000	0.006	0.000	0.001	1.177	11.579	14.673	8.425	21.738	19.576
Error (b)	36	0.000	0.002	0.002	0.002	2.434	4.965	44.056	68.328	43.781	67.139

APPENDIX-XXX

Analysis of variance for available nutrients (kg ha^{-1}) in soil.

Source of variation	d.f.	Mean sum of square for available nutrients							
		Nitrogen		Phosphorous		Potassium		Organic carbon (%)	
		2019	2020	2019	2020	2019	2020	2019	2020
Replication	3	1524.792	1649.215	8.596	8.670	1140.927	1219.892	0.008	0.009

Establishment methods (E)	2	61.661	66.692	6.038	4.062	279.356	179.845	0.002	0.000
Error (a)	6	292.373	316.231	1.746	1.809	220.428	237.728	0.001	0.002
Weed management options (W)	4	446.592*	483.034*	25.947*	20.265*	938.713*	1130.262*	0.002	0.002
Interaction (E×W)	8	2.239	2.422	3.643	8.284	5.866	9.319	0.001	0.001
Error (b)	36	164.202	177.600	1.802	2.839	125.885	135.422	0.001	0.001

APPENDIX-XXXI

Analysis of variance for Economics

Source of variation	d.f.	Mean sum of square for economics					
		Gross Return (Rs ha^{-1})		Net Return (Rs ha^{-1})		Benefit: Cost Ratio	
		2019	2020	2019	2020	2019	2020
Replication	3	369771276.18	53489220546.66	369814239.54	534869347.47	0.241	0.364
Establishment methods (E)	2	2445684751.83*	1512461301.36*	1781801737.08*	944899297.68*	1.387*	0.987*
Error (a)	6	90596784.77	85223072.04	90592770.28	85224278.95	0.053	0.056
Weed management options (W)	4	5475573807.85*	5382578706.61*	4784902734.03*	4720204662.96*	3.042*	2.857*
Interaction (E×W)	8	8842684.87	9175977.43	8836168.46	9183733.56	0.011	0.011
Error (b)	36	53585068.44	49026107.72	53581962.99	49027691.47	0.037	0.032

APPENDIX-XXXII

Common cost of cultivation (*kharif* 2019 & 20) of the experimental rice (Rs/ha)

Sr.	Particulars	Description		Total cost (Rs.)	
		2019	2020	2019	2020
1	**Land preparation**				
i	Pre sowing irrigation + one labour	600+188	700+190	788	890
ii	One deep ploughing by tractor drawn M.B. Plough	800 ha^{-1}	800 ha^{-1}	800	800
iii	Two cross ploughing by tractor drawn cultivator + Planking	750 ha^{-1}	750 ha^{-1}	1500	1500
iv	Making of bunds and channels (8 labours)	188 $labour^{-1}$	190 $labour^{-1}$	1504	1520
2	**Nursery raising and planting**				
i	Cost of seed (30 kg/ha)	65 kg^{-1}	65 kg^{-1}	1950	1950
ii	Cost of nursery raising	1000	1000	1000	1000
iii	Cost of transplanting (20 labour)	20×188	20×190	3760	3800
3	**Fertilizers**				
i	Urea – 162 kg	7 kg^{-1}	7 kg^{-1}	1131	1131
ii	D.A.P – 87kg	22 kg^{-1}	22 kg^{-1}	1912	1912
iii	M.O.P – 67kg	16 kg^{-1}	16 kg^{-1}	1066	1066
iv	$ZnSO_4$ (25 kg /ha)	50 kg^{-1}	50 kg^{-1}	1250	1250
v	Labour used in application (2 labour)	188 $labour^{-1}$	190 $labour^{-1}$	376	380
4	**Irrigation**				
		60 Rs/ hr.	70 Rs/ hr.		
i	Conventional puddled irrigations cost	10 hrs $irrigation^{1}$ Total= 10	10 hr $irrigation^{1}$ Total= 10	-	-
ii	Unpuddled flat irrigation cost	8 hr $irrigation^{-1}$ Total=10	8 hr $irrigation^{-1}$ Total=10	-	-
iii	Furrow irrigated raised bed irrigation cost	5 hr $irrigation^{-1}$ Total=11	5 hr $irrigation^{-1}$ Total=11	-	-
5	**Plant protection**				
i	Cartap hydrochloride 4G @ 20 kg ha^{-1}	60 kg^{-1}	60 kg^{-1}	1200	1200
ii	Labour used in application (1 labour)	188 $labour^{-1}$	190 $labour^{-1}$	188	190
6	Harvesting and Threshing (30 labours)	30×188	30×190	5640	5700
7	Land rent for crop	3000 $year^{-1}$	3000 $year^{-1}$	1500	1500
8	Interest on working capital for 6 months	12% annum	12% annum	1534	1547
9	Miscellaneous	500	500	500	500
Total cost				**27599**	**27836**

Appendix- XXXIII

Prices of input and output used in the experiment

Sr. No.	Particulars	Cost (Rs.)	
		2019	**2020**
A	**Input**		
i	Labour	188 labour^{-1}	190 labour^{-1}
ii	Irrigation	60 Rs./hr irrigation	70 Rs./hr irrigation
iii	Urea	7 kg^{-1}	7 kg^{-1}
iv	Di ammonium phosphate (DAP)	22 kg^{-1}	22 kg^{-1}
v	Muriate of potash (MOP)	16 kg^{-1}	16 kg^{-1}
vi	Zink Sulphate ($ZnSo_4$)	50 kg^{-1}	50 kg^{-1}
vii	Cartap hydrochloride 4G	60 kg^{-1}	60 kg^{-1}
viii	Puddling	2600 ha^{-1}	2600 ha^{-1}
ix	Beds preparation	1000 ha^{-1}	1000 ha^{-1}
x	Pretilachlor	334 Litre^{-1}	334 Litre^{-1}
xi	Almix	56 g^{-1}	56 g^{-1}
xii	Bispyribac sodium	480/100ml	480/100ml
B	**Output**		
i	Rice grains	2500 q^{-1}	2500 q^{-1}
ii	Rice straw	180 q^{-1}	180 q^{-1}

ABSTRACT

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Thesis title: Effect of crop establishment methods and weed management options on weed dynamics and performance of Basmati rice (*Oryza sativa* L.).

A field experiment entitled "Effect of crop establishment methods and weed management options on weed dynamics and performance of Basmati rice (*Oryza Sativa* L.)" was carried out at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut-250110 (U.P.)during *kharif* season of 2019 and 2020. Experiment was laid out in split plot design with four replications. Main factors consist of the crop establishment methods *viz.* (1) Conventional Puddled Transplanting (CPT), (2) Unpuddled Flat (UPF) and (3) Furrow Irrigated Raised Beds (FIRB) and the sub factors consist of five weed management options *viz.*, (1) Pretilachlor @ 0.75 Kg ha^{-1} PE *fb* Bispyribac sodium @ 20 g a.i. ha^{-1} PoE at 20 DAT, (2) Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1} PoE at 20 DAT, (3) Bispyribac sodium @ 25 g a.i. ha^{-1} PoE at 20 DAT, (4) Two hand weedings and (5) Weedy check.

Results revealed that among all the crop establishment methods,conventional puddled transplanting (E_1) exhibited significant influence on the growth, yield attributes and yield of basmati rice followed by furrow irrigated raised bed method (E_3) and the lowest growth, yield attributes and yield were found under unpuddled flat method (E_2) during both the years. However, furrow irrigated raised bed method (E_3) showed better effect on yield attributes, soil properties and profitability of rice. Among the different treatments, two manual weeding to keep the plot weed free was the most effective weed control measure which resulted in higher value of weed control efficiency andit was statistically at par to Pretilachlor @ 0.75 kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} and Almix 4 g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}. Highest growth parameters, yield and yield attributes of rice and nutrient uptake was noticed with the application of Pretilachlor @ 0.75 kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1}. Among herbicide treatments Pretilachlor @ 0.75 kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} was found excellent in gross return, net return, and B: C ratio which was at par with the Almix 4g a.i. ha^{-1} + Bispyribac sodium @ 20 g a.i. ha^{-1}. Thus, the application of pretilachlor @ 0.75 kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} seems better for higher productivity and profitability of rice. Therefore, furrow irrigated raised bed method with pretilachlor @ 0.75 Kg ha^{-1}*fb* Bispyribac sodium @ 20 g a.i. ha^{-1} weed management option proved to be better.

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VITAE

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