Effect of nano encapsulated pendimethalin on growth attributes of rice

ABSTRACT

Weed infestation is a major problem in upland rice of Kerala.Pendimethalin is a selective pre-emergent herbicide used to control broad-leaved and grassy weeds in rice fields. However, herbicides like pendimethalin often face losses in the agroecosystem through various pathways, reducing their effectiveness and potentially contaminating the environment, including groundwater. Encapsulation of herbicides is an innovative method designed to enhance their efficacy while minimizing environmental contamination, making herbicide application more efficient for weed control.A field experiment was carried out at the Instructional Farm, ~~of the~~ College of Agriculture, Vellayani, Kerala, India to evaluate the effect of nano encapsulated pendimethalin for weed management in upland rice.Synthesis of nano encapsulated pendimethalin was done at Department of Agronomy, College of Agriculture,Vellayani.The study revealed that nano encapsulated pendimethalin had significant influence on growth attributes over normal commercial formulations. Among all the growth parametersNano Encapsulated Pendimethalin(NEP) with 4% starch aqueous phase at 1.0 kg ha^{-1}showed comparable result with hand weeding at 15 and 30 Days After Sowing (DAS). The nano encapsulated formulation had a particle size of 486.6 nm and zeta potential of -18 mV.

Key words: Pendimethalin, nano encapsulation, plant height, leaf area index

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple food crops in the world and it occupies a pivotal position in the food security system in India. Uncontrolled weed infestation in upland rice accounts for 42%–100% yield reductions[1]. Pendimethalin is a selective pre-emergent herbicide used to control broad leaved and grassy weed species in rice. However, the applied herbicides undergo losses in the agroecosystem in different ways (chemical degradation, microbial decomposition, photo-degradation, leaching, run-off, and volatilization), thus lowering the herbicidal action coupled with contaminating ecosystem and groundwater[AddReference]. Encapsulation of herbicides is an innovative approach that addresses issues associated with the application of herbicides for controlling weeds. Further, encapsulation lowers the application rate of herbicides, which in turn reduces the residue carryover of herbicide in soil and minimizes the environmental hazards. Therefore, encapsulated herbicide formulation has greater significance in the future weed management and will become ground-breaking technology in the chemical era of weed control. Herbicide encapsulation is a versatile technology performed at nano and micro-scale by incorporating active ingredients into the suitable carrier. Nano encapsulation of pendimethalin with natural polymers like starch helps in slow and safe release of the herbicide into soil in required concentration thereby controlling its indiscriminate use and aids in season long weed control(Add Reference). Nanotechnology opens a door for safe & efficient delivery of active ingredient, improved solubility, reduced environmental impact while maintaining bioactivity and prolonged release in soil. Nano herbicide through its rapid penetration ability kills the weed before it could develop resistance against the herbicide[2].

2. MATERIALS AND METHODS

The field experiment was carried out at the Instructional Farm, ~~of the~~College of Agriculture, Vellayani, Kerala, India. The farm is located at a latitude of 8°42'85"N and longitude of 76°98'74" E at an altitude of 29 m above MSL.The chosen variety of rice for the study was a short duration variety KAU Manuratna. Synthesis of nano encapsulated pendimethalin was

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carried at College of Agriculture Vellayani. The characterization studies were conducted at CSIR-NIIST,(Add City name).

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2.1 Synthesis and characterization of nano encapsulated pendimethalin

Pendimethalin 1 mg was dispersed in 4 ml of acetone solvent and sonicated with energy output 25 W under continuous mode for 90 seconds. Poly ethylene glycol polymer of 20 mg was dissolved in 8 ml of dichloromethane solvent and sonicated with energy output 25 W under continuous mode for 90 seconds. Both were mixed well to form organic phase.Took 4 ml of starch polymer with different concentrations (4 and 6 per cent) and stirred with a magnetic stirrer for one hour for the preparation of aqueous phase.The organic phase containing the polymer with herbicide was added drop wise to aqueous phase containing the different starch concentrations to form oil in water phase. It was sonicated with energy output of 25 W under continuous mode for 90s. Then formed oil in water phase was stirred overnight inamagnetic stirrer under room temperature. The nanoparticles produced were collected by centrifugation with 5000 rpm for 15 min under room temperature and dried in vacuum desiccators. The dried particles were collected and stored in vial [3].

Zeta Potential (Z.P)

Using Zetasizer Nano ZS, Malvern equipment, dynamic light scattering (DLS) the mean zeta potential, electrophoretic mobility and conductivity of nanoparticles were measured at 25°C and at a scattering angle of 90°. Here, one ml of nano encapsulated pendimethalin nanoparticles were dispersed in 200 ml of distilled water containing 1% acetone followed by sonication for 60 min. The samples were kept cold by an external ice bath during sonication process.

Particle size distribution

The average hydrodynamic diameter, size distribution and polydispersity index (PDI) of nanoparticles were measured using a Particle Size Analyzer (Brookhaven, NY, USA) at 25°C and scattering angle of 90°. Sample was prepared by dispersing one ml in 200 ml of distilled water containing 1% acetone followed by 60 min sonication in an ice bath. Particle size was determined based on laser beam scattering technique.

Fourier- transform infrared (FT-IR) spectroscopy

FT-IR spectra were recorded using a PerkinElmer Spectrum IR Version 10.6.0 through attenuated total reflectance (ATR) using 4 cm^{-1} resolution and 32 scans per spectrum in the range of 500-4000 cm^{-1}.For taking the spectrum, sample was placed on the diamond crystal and gripper plate was placed on the sample to ensure required contact between crystal and sample. The measurement was taken 16 times for each trial and their average was taken.

2.2 Growth attributes of rice

Plant height and leaf area index were recorded at 30 DAS, 45 DAS and 60 DAS. Number of tillers m^{-2} was recorded at 30 DAS and 45 DAS.

2.3Treatment details

There were nine treatments replicated thrice. Different treatments includedT_1(NEP with 4% starch aqueous phase 0.5 kg ha^{-1}), T_2 (NEP with 4% starch aqueous phase 0.75 kg ha^{-1}), T_3(NEP with 4% starch aqueous phase 1.0 kg ha^{-1}), T_4 (NEP with 6% starch aqueous phase 0.5 kg ha^{-1}), T_5 (NEP with 6% starch aqueous phase 0.75 kg ha^{-1}), T_6 (NEP with 6% starch aqueous phase 1.0 kg ha^{-1}), T_7 (Pendimethalin 1.0 kg ha^{-1}), T_8 (Hand weeding (HW) at 15 and 30 DAS),T_9 (Weedy check). Here NEP stands for nano encapsulated pendimethalin.The statistical design employed for the study was randomized complete block design.

3. RESULTS

Characterization studies

The particle size analysis of the sample revealed an average size of 486.6 nm for NEP with 4% starch aqueous phase 1.0 kg ha^{-1}. Zeta potential data showed incipient stability range forNEP with 4% starch aqueous phase 1.0 kg ha^{-1} (-18 mV). FTIR results showed a peak at 3339.67 cm^{-1}. This peak was in the region where N-H stretching was observed, which corresponded to the secondary amine group present in pendimethalin. It showed another peak at 1635.21 cm^{-1} and was consistent with aromatic C=C stretching, which fits pendimethalin's structure since it had aromatic rings. Another peak was observed at3339.67 cm^{-1},which corresponded to the O-H stretching vibration, which was present in starch due to the hydroxyl groups involved in hydrogen bonding. Also, it indicated the presence of polyethylene glycol.

Weed dry weight

There were significant variations among treatments with respect to total dry weight of weeds at 30 DAS and 45 DAS. At 30 DAS lower weed dry weight was observed in T_3 (10.54g) which was onpar with T_6 (11.32g) and T_8 (12.42g). At 45 DAS the lowest weed dry weight was observed in T_8 (13.78g) followed by T_3 (32.50g) and T_6 (35.10g). At both the intervals T_9 recorded the highest weed dry matter production (35.10g and 110.26g respectively).

Table 1: Effect of NEP on weed dry weight

Treatments	Weed dry weight (g)	
	30 DAS	**45 DAS**
T_1 –NEP with 4% starch aqueous phase 0.5 kg ha^{-1}	19.70	54.93
T_2 – NEP with 4% starch aqueous phase 0.75 kg ha^{-1}	17.89	47.20

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T_3 – NEP with 4% starch aqueous phase 1.0 kg ha^{-1}	10.54	32.50
T_4 – NEP with 6% starch aqueous phase 0.5 kg ha^{-1}	22.72	61.66
T_5 - NEP with 6% starch aqueous phase 0.75 kg ha^{-1}	20.16	58.20
T_6 - NEP with 6% starch aqueous phase 1.0 kg ha^{-1}	11.32	35.10
T_7 - Pendimethalin 1.0 kg ha^{-1}	21.20	52.53
T_8 - Hand weeding at 15 and 30 DAS	12.42	13.78
T_9-Weedy check	63.53	110.26
SEm(±)	1.469	23.76
CD(P=0.05)	4.405	8.437

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Growth attributes

Plant height of rice depicted significant variation among treatments at 30 DAS, 45 DAS and 60 DAS (Fig. 1). At 30 DAS(58.21 cm), 45 DAS(78.21) and 60 DAS(83.38) taller plantswere observed in hand weeding at 15 and 30 DAS (T_8) which was followed byT_3i.e.,NEP with 4% starch aqueous phase 1.0 kg ha^{-1}(52.03 cm, 72.03 cm and 77.12 cm, respectively). Among all treatments the shortest plants were observed in weedy check at 30 DAS (32.40 cm), 45 DAS (52.40 cm) and 60 DAS (57.48 cm),respectively.

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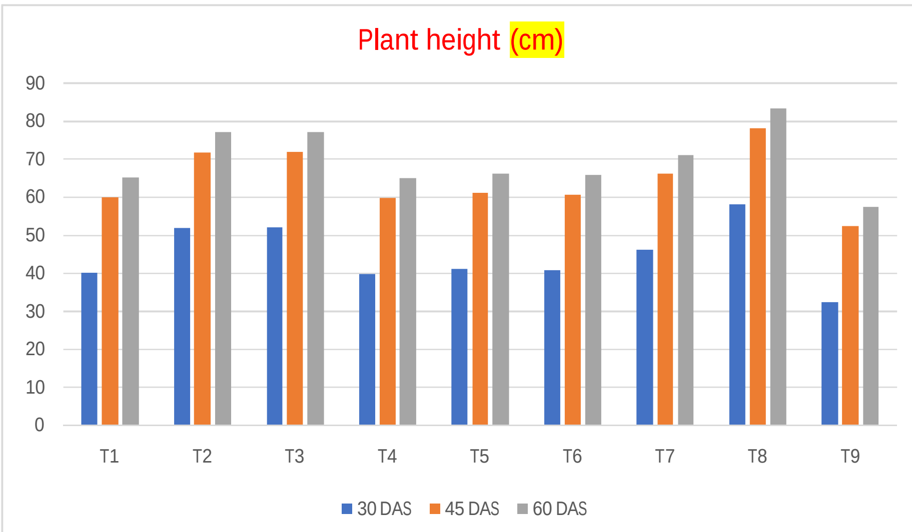

Fig. 1: Effect of NEP on plant heightof rice at 30 DAS, 45 DAS and 60 DAS

There were significant variations among treatments with respect to number of tillers m^{-2} at 30 DAS and 45 DAS (Fig. 2). At 30 DAS higher number of tillers m^{-2} (409.33) were observed in HW twice which was on par with T_3(406.67) and T_6 (401.33).At 45 DAS, maximum number of tillers m^{-2} (460.00) was observed inT_3 which was on par with T_8(442.67). At 30 DAS and 45 DAS, minimum number of tillers m^{-2} (309.33 and 325.33) was recorded in weedy check (T_9).

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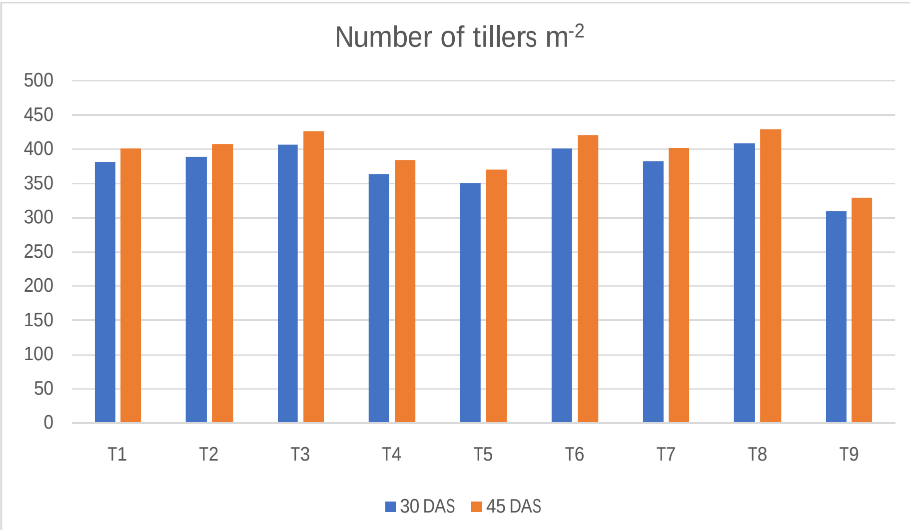

Fig. 2 Effect of NEP on number of tillers m^{-2} of rice

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With respect to total dry matter production Hand weeding twice recorded higher dry matter production (7041.24 kg ha^{-1}) and was comparable with T_3 (6425.01 kg ha^{-1}) (Fig. 3). The lowestwas observed in weedy check (3696.13~~3~~kg ha^{-1}).

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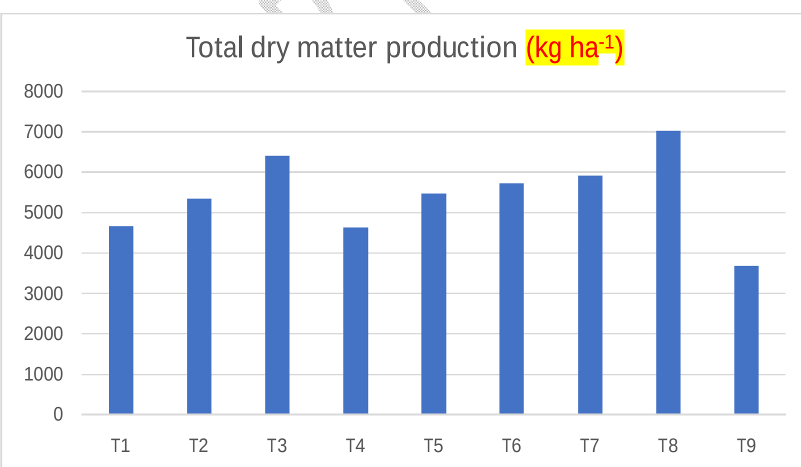

Fig. 3 Effect of NEP on total dry matter productionof rice

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Significant variation was noticed in Leaf Area Index (LAI) at 30 DAS, 45 DAS and 60 DAS (Fig. 4). Higher leaf area index was shown by T_3 at 30 DAS (3.22), 45 DAS (4.11) and 60 DAS (4.23).

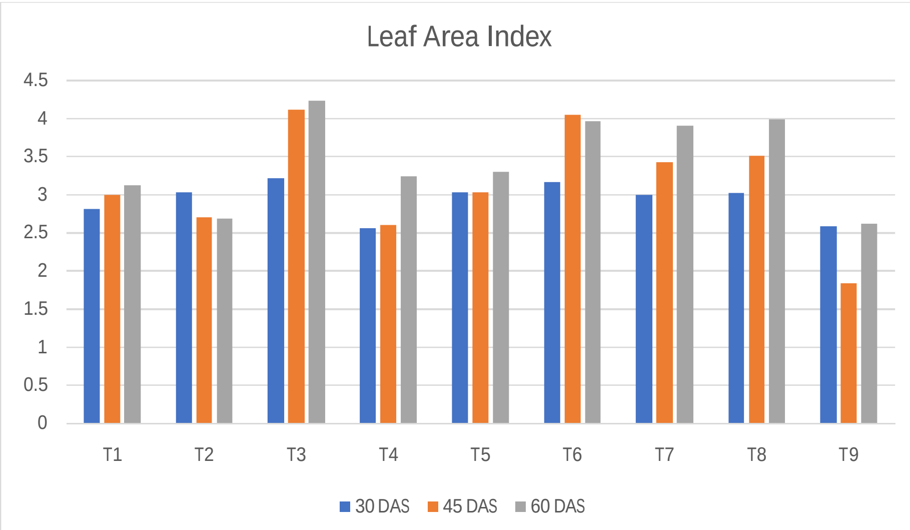

Fig. 4 Effect of NEPon leaf area index of rice

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DISCUSSION

Effective weed control created a favorable environment for crop growth by improving the availability of moisture, nutrients, and sunlight. This, in turn, indirectly increased the total chlorophyll content and photosynthetic rate, leading to higher carbohydrate accumulation. As a result, there was an increase in the number of tillers per meter square, leaf area index, and total dry matter production in rice[4].Thecrops competed with weeds for the resources available, which led to inadequacy of nutrients resulted in reduced drymatter accumulation of crop [5]. These results were in accordance with the findings of Vimalrajiv *et al.* (2018) [6].Effective weed control through slow release of nanoformulation likely created a more favorable environment for plant growth, enabling improved nutrient uptake. These results were in accordance with the findings ofBommayasamy and Chinnamuthu (2021) [7], who observed an increased number of tillers m^{-2}, longer panicles, heavier panicles, and a higher number of filled grains per panicle with oxadiargyl-entrapped zeolite and oxadiargyl-entrapped biochar. Encapsulating herbicides led to enhanced weed control, which in turn facilitated better nutrient uptake by the crop.

4. CONCLUSION

Among all the weed management treatments, Hand weeding at 15 DAS and 30 DAS showed significantly higher growth attributes which was comparable with NEP with 4% starch aqueous phase 1.0 kg ha^{-1}. In case of weed dry weightat 30 and 45 DAS NEP with 4% starch aqueous phase 1.0 kg ha^{-1}significant effect over other treatments.Nano encapsulated formulation of pendimethalin exhibited higher bio efficacy on weeds and depicted significant influence on growth attributes over normal commercial formulations.

5. REFERENCES

1.Kolo, E., Adigun, A.J., Adeyemi, R.O., Daramola, S.O. and Bodunde, J.G. 2021. The effect of weed control timing on the growth and yield of upland rice (*Oryza sativa*L.). *J. Agric. Sci. (Belgrade)*. 66(1): 27-38.

2. Manjunatha, S.B., Biradar, D.P. and Aladakatti, Y.R. 2016. Nanotechnology and its applications in agriculture: A Rev. *J*. *Farm Sci*. 29(1): 1-13.

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3. Kumar, P. and Chinnamuthu, C.R. 2017. Assembly of nanoencapsulated pendimethalin herbicide using solvent evaporation method for season long weed control under irrigated ecosystem. *Int. J. Pure App. Biosci*. 5(1): 349-357.

4. Raj, S.K. and Syriac, E.K. 2018. Herbicide mixtures effect on weed seed bank in direct-seeded rice. *Indian J. Weed Sci.* 50(1): 64-68.

5. Vimalrajiv, B., Chinnamuthu, C.R., Subramanian, E. and Senthil, K., 2019. Management of weed seed bank using nanoparticles in combination with pendimethalin and hydrogen peroxide in irrigated blackgram (*Vigna mungo*L.). *Madras Agricultural Journal, 106*(march (1-3)), p.1.

6. Vimalrajiv, B., Chinnamuthu, C.R., Subramanian, E. and Senthil, K., 2018. Effect of nanoparticles in combination with pendimethalin and hydrogen peroxide on growth parameters and nodulation of blackgram (*Vigna mungo*L.). *International Journal of Communication and Society*, *6*(3), pp.2816-2819.

7. Bommayasamy, N. and Chinnamuthu, C.R. 2021. Effect of encapsulated herbicides on weed control, productivity and nutrient uptake of rice (*Oryza sativa*). *J. Environ. Biol.* 42(2): 319-325.

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