Assessing the Nutrient balance and Nutrient use efficiency of various concentration of Low-Density polyethylene (LDPE) on green gram (*Vigna radiata L. Wilczek*) Cultivation

ABSTRACT

Aims: To assessing the nutrient balance and nutrient efficiency of green gram crop under various levels of LDPE incubation
Study design: Complete Randomised Design (CRD)
Place and Duration of Study: The pot experiment was conducted at Instructional farm (North), Karunya Institute of Technology and Sciences, Coimbatore
Methodology: To Study the balance of accessible nutrients (N, P, and K) in the soil throughout crop production was calculated for each treatment based on the particular nutrient application that was provided to the green gram crop similarly the total amount of nutrient removal and Nutrient Efficiency of N, P and K was calculated.
Results: The treatments of 5%,7%,7.5% and 8% concentration of LDPE showed a very negligible results in nutrient balance studies and in the efficiency of Agronomic and physiological and apparent recovery studies.
Conclusion: The chance of entering microplastic in to soil ecosystem under green gram cultivation

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Keywords*:* Microplastics, Low-Density Polyethylene (LDPE), green gram,Nutrient balance studies

1. INTRODUCTION

Plastic pollution has emerged as a critical environmental concern, encompassing both macro plastics (large plastic waste) and microplastics (minute plastic fragments), which pose substantial risks to ecosystems and human well-being**[1].** Unlike macro plastics, which are conspicuous and commonly stem from discarded objects such as bottles and bags, microplastics are nearly invisible to the naked eye **[2].** Microplastics are tiny plastic fragments, usually smaller than 5 millimeters across. They come from two main sources: direct emissions of small pellets used in different commercial and industrial applications (known as primary microplastics) and the breakdown of larger plastic items into smaller pieces (known as secondary microplastics)**[3].** The ubiquitous presence of microplastics in various environments, such as oceans, rivers, and soils, raises significant concerns. These concerns include the potential harm to wildlife and human health, stemming from the ingestion of these particles and exposure to the chemicals they contain **[4].**

Microplastics' effects on a variety of crops have revealed important implications on physiological processes, soil health, and growth. maize plants exposed to microplastics had shorter roots, lower biomass, and lower levels of photosynthetic pigment, along with altered soil microbial communities **[5].** Reduced germination of wheat seeds, hindered root development, and changes in the microbial composition of soil after exposure to microplastics, which could endanger soil ecosystems and wheat yield **[6].** Furthermore [**7]**observed that the presence of microplastics in tomato environments resulted in altered fruit traits, reduced fruit yield, and disruptions in soil microbial communities. These findings raise concerns for the health of the soil and tomato production in areas where microplastics are present. Together, these studies highlight the wide-ranging and harmful impacts of microplastics on crop growth, soil quality, and agricultural productivity**[8]**

Microplastics have a major impact on soil ecosystems. by changing the porosity and water dynamics of the soil, they physically alter its structure, hence influencing patterns of infiltration and retention **[9].** The biological disruption caused by microplastics causes changes in the variety and activity of soil microbial communities, which include bacteria, fungus, and archaea **[10]** the transportation of microplastics poses a risk to aquatic ecosystems and groundwater because they can move through soil profiles, reach deeper layers, and be rinsed away by water **[11].** Their ecotoxicological effects are also rather strong since they operate as pollution carriers, increasing the amount of toxic compounds that organisms are exposed to toxic substances **[12]**Microplastics possess the capability to alter nutrient cycling by adsorbing nitrogen and phosphorus, thereby diminishing their accessibility to aquatic organisms **[13].**

2. MATERIAL AND METHODS

2.1 EXPERIMENTAL LOCATION AND CLIMATE CONDITION

The pot experiment was conducted at Instructional farm (North), Karunya Institute of Technology and Sciences, Coimbatore. The experimental site is geographically located in the western agro- climatic zone of Tamil Nadu at 11º N latitude and76º E longitude at an altitude of 427 m above mean sea level.

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Fig . 1 Map showing study location and samples

2.2 Season and crop variety

The study was conducted during the season of *rabi* on January 2024. The variety for this green gram is co (Gg) 8 with a duration of 55- 60 days

2.3. Experimental design

The pot trial was laid out in Complete Randomized design (CRD) comprising of three replications and nine treatments. The treatment details are in Table 1. The methods are employed to collect the data on crop uptake and soil available nutrients soil at 15 DAS, 30 DAS and at harvest stage respectively. It is expressed in kg ha^{-1}.

Table 1. Treatment Details

T_1	:	Absolute control (Without fertilizers and Microplastic)
T_2	:	Control (Without Microplastic)
T_3	:	0.5 % of Low-Density Polyethylene (LDPE)
T_4	:	1.0 % of Low-Density Polyethylene (LDPE)
T_5	:	3.0 % of Low-Density Polyethylene (LDPE)
T_6	:	5.0 % of Low-Density Polyethylene (LDPE)
T_7	:	7.0 % of Low-Density Polyethylene (LDPE)
T_8	:	7.5 % of Low-Density Polyethylene (LDPE)
T_9	:	8.0 % of Low-Density Polyethylene (LDPE)

Note:

The grow (5 kg capacity) bag was selected and filled with top 45 cm soil from the Instructional farm (North) at Karunya Institute of Technology and Science, Coimbatore and the weight / weight basis, to filled the calculated amount of LDPE and recommended dose of fertilizers

Table 2 Initial soil status

Available N (kg ha^{-1})	259	Alkaline permanganate method	**[14]**
Available P (kg ha^{-1})	8.9	Olsen's method	**[15]**
Available K (kg ha^{-1})	286	Flame photometer method	**[16]**

2.4. Plant uptake analysis

Crop samples are collected at harvest stage for estimation of dry matter production are used for analysis. The oven dried samples are chopped and using ground Willey mill for analysis the N,P and K contents from the standard procedure

Table 3 Analysis ofN,P and K contents from the standard procedure

Particulars	Methods used	Reference
N (%)	Modified micro kjeldahl method	**[16]**

P (%)	Vanado-molybdo phosphoric yellow colour method using spectrophotometer	**[16]**
K (%)	Flame photometry method	**[16]**

Nutrient uptake was used by the following formula and expressed in kg/ha

$$Nutrient\ uptake\ (kg/ha) = \frac{per\ content\ nutrient\ content\ \times\ total\ dry\ matter\ production\ (kg/ha)}{100}$$

2.5. Crop Management

The crop was sown (one seed) in poly bag and it was replicated three times. The Recommended dose of fertilizer is 25:50:25 kg ha^{-1}, weeding, irrigation and agronomic practices were followed by crop production guide 2023.

2.6. Nutrient balance studies

Soil available nutrient (N, P and K) balance in the crop production was computed for the treatments as per the specific nutrient added to the green gram crop and the same manner the total quantity of nutrient removal was also computed. The specific nutrient's computed balance was derived from total quantity of the specific nutrient added was subtracted from the total quantity of the specific nutrient removed. The specific nutrient balance was computed from the soil specific nutrient status at harvest was subtracted from the specific nutrient status at initial as per the procedure **[17]** and the nutrient balance (either positive or negative) was expressed in kg ha^{-1}.

2.7. Agronomic efficiency (AE)

The agronomic efficiency i.e. the response in yield per unit input as indicated by the following formula **[18].**

$$AE = \frac{Grain\ yield\ in\ fertilized\ plot\ (kg\ /ha)\ -\ Grain\ yield\ in\ unfertilized\ plot(kg\ /ha)}{Quantity\ of\ nutrient\ applied\ (kg/ha)}$$

2.8. Apparent nutrientrecovery

Apparent nutrient recovery, also known as recovery fraction was computed as per the formula **[19].**

$$AR = \frac{Yt\ - Yo}{Nt} \times 100$$

Where,

Yt - Uptake of nutrient in particular treatment (kg ha^{-1}),

Y0 - Uptake of nutrient in unfertilized plot (kg ha^{-1}), and

Nt - Quantity of nutrient applied for the treatment (kg ha^{-1}).

3. RESULTS AND DISCUSSION

3.1. NUTRIENT BALANCE STUDIES

The positive result indicates a gaining nutrient in soil pool and negative results indicated loss of nutrient in soil pool. The investigation observed that negative response in the nitrogen under absolute control followed by control, 0.5% concentration of LDPE (-1, -7, -6 kg ha^{-1}) and 1% concentration of LDPE (- 4 kg ha^{-1}). The positive response in nitrogen was recorded in the LDPE concentrations of 3%, 5%, 7%, 7.5%, and 8% respectively. There was no nutrient loss recorded in control, Absolute control and in all the levels of LDPE treatments respectively, in phosphorous and the potassium nutrient balance expect the control (- 6 kg ha^{-1}) and 0.5% LDPE concentration (-2 kg ha^{-1}) treatments were observed the positive response. However, the nitrogen response in control and 0.5% concentration of LDPE in phosphorous showed minimal negative effects. This type of negative response in soil pool due to the presence of LDPE and it was accumulated in the roots, they may harm to crop growth (lesser ability to absorb water & nutrients from the soil) **[20]** and indirectly alter the microbiota, nutrients, and soil qualities, potentially negatively influencing crop yield**[21].**

However the uptake of nutrient by the plant is more so, the negative response was observed. As the higher concentration of LDPE distributing the root surface the nutrients are not uptake by the crop then the positive response was recorded.

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Table 4. Nutrient balance studies on nitrogen (kg ha^{-1})

	Treatments	Initial Soil (A)	N applied to the crop (B)	N removal (C)	Computed balance (B - C)	Soil N at Harvest (D)	Net gain or loss (E) (D-A)
T1	Absolute control (Without fertilizers and Microplastic)	260	0	92	-92	259	-1
T2	Control (Without Microplastic)	260	87.5	111	-23.5	253	-7
T3	0.5 % of Low-Density Polyethylene (LDPE)	260	87.5	106	-18.5	254	-6
T4	1.0 % of Low-Density Polyethylene (LDPE)	260	87.5	97	-9.5	256	-4
T5	3.0 % of Low-Density Polyethylene (LDPE)	260	87.5	95	-7.5	259	-1
T6	5.0 % of Low-Density Polyethylene (LDPE)	260	87.5	88	-0.5	261	1
T7	7.0 % of Low-Density Polyethylene (LDPE)	260	87.5	85	2.5	262	2
T8	7.5 % of Low-Density Polyethylene (LDPE)	260	87.5	82	5.5	264	4
T9	8.0 % of Low-Density Polyethylene (LDPE)	260	87.5	77	10.5	265	5

Table 5. Nutrient balance sheet on phosphorous (kg ha^{-1})

	Treatments	Initial Soil (A)	P applied to the crop (B)	P removal (C)	Compute d balance (B - C)	Soil P at Harvest (D)	Net gain or loss (E) (D-A)
T1	Absolute control (Without fertilizers and Microplastic)	8.9	0	26.5	-26.5	52	43.1
T2	Control (Without Microplastic)	8.9	81.25	32.4	48.85	50	41.1
T3	0.5 % of Low-Density Polyethylene (LDPE)	8.9	81.25	30	51.25	51	42.1
T4	1.0 % of Low-Density Polyethylene (LDPE)	8.9	81.25	26.5	54.75	52	43.1
T5	3.0 % of Low-Density Polyethylene (LDPE)	8.9	81.25	30.5	50.75	51	42.1
T6	5.0 % of Low-Density Polyethylene (LDPE)	8.9	81.25	23	58.25	53	44.1
T7	7.0 % of Low-Density Polyethylene (LDPE)	8.9	81.25	22.5	58.75	54	45.1
T8	7.5 % of Low-Density Polyethylene (LDPE)	8.9	81.25	19.5	61.75	55	46.1
T9	8.0 % of Low-Density Polyethylene (LDPE)	8.9	81.25	15.5	65.75	56	47.1

Table 6. Nutrient balance sheet of Potassium (kg ha^{-1})

	Treatments	Initial Soil (A)	K applied to the crop (B)	K removal (C)	Computed balance (B - C)	Soil K at Harvest (D)	Net gain or loss (E) (D-A)
T1	Absolute control (Without fertilizers and Microplastic)	286	0	80	-80	288	2
T2	Control (Without Microplastic)	286	56.25	98	-41.75	280	-6
T3	0.5 % of Low-Density Polyethylene (LDPE)	286	56.25	89	-32.75	284	-2
T4	1.0 % of Low-Density Polyethylene (LDPE)	286	56.25	78	-21.75	288	2
T5	3.0 % of Low-Density Polyethylene (LDPE)	286	56.25	84	-27.75	286	0
T6	5.0 % of Low-Density Polyethylene (LDPE)	286	56.25	75	-18.75	289	3
T7	7.0 % of Low-Density Polyethylene (LDPE)	286	56.25	72	-15.75	290	4
T8	7.5 % of Low-Density Polyethylene (LDPE)	286	56.25	69	-12.75	291	5
T9	8.0 % of Low-Density Polyethylene (LDPE)	286	56.25	66	-9.75	292	6

3.2. Agronomic efficiency

The agronomic efficiency was calculated for N, P and k under various levels of LDPE, the higher concentration of LDPE treatment (5, 7, 7.5 and 8 per cent respectively) recorded the lower (negative response) efficiency however the lower concentration of LDPE treatments (0.5, 3 and 1) recorded higher (positive response) efficiency. And the fertilizer applied and without incubation of LDPE treatment recorded the better and high positive response compare with all the treatment **[22].**

Table 7. Agronomic efficiency of Nitrogen

Treatments		Treated plot yield	Control yield	Treated yield - control plot yield	N applied to the crop	Agronomic efficiency N
		(kg ha^{-1})				
T1	Absolute control (Without fertilizers and Microplastic)	-	-	-	-	-
T2	Control (Without Microplastic)	850	698	850	87.5	9.71
T3	0.5 % of Low-Density Polyethylene (LDPE)	814	698	116	87.5	1.32
T4	1.0 % of Low-Density Polyethylene (LDPE)	704	698	6	87.5	0.06
T5	3.0 % of Low-Density Polyethylene (LDPE)	788	698	90	87.5	1.02
T6	5.0 % of Low-Density Polyethylene (LDPE)	653	698	-45	87.5	-0.51
T7	7.0 % of Low-Density Polyethylene (LDPE)	602	698	-96	87.5	-1.09
T8	7.5 % of Low-Density Polyethylene (LDPE)	588	698	-110	87.5	-1.25
T9	8.0 % of Low-Density Polyethylene (LDPE)	576	698	-122	87.5	-1.39

Table 8. Agronomic efficiency of Phosphorous (kg ha^{-1})

Treatments		Treated plot yield	Control yield	Treated yield – control plot yield	P applied to thecrop	Agronomic efficiency P
		(kg ha^{-1})				
T1	Absolute control (Without fertilizers and Microplastic)	-	-	-	-	-
T2	Control (Without Microplastic)	850	698	152	81.25	1.87
T3	0.5 % of Low-Density Polyethylene (LDPE)	814	698	116	81.25	1.42
T4	1.0 % of Low-Density Polyethylene (LDPE)	704	698	6	81.25	0.07
T5	3.0 % of Low-Density Polyethylene (LDPE)	788	698	90	81.25	1.10
T6	5.0 % of Low-Density Polyethylene (LDPE)	653	698	-45	81.25	-0.55
T7	7.0 % of Low-Density Polyethylene (LDPE)	602	698	-96	81.25	-1.18
T8	7.5 % of Low-Density Polyethylene (LDPE)	588	698	-110	81.25	-1.35
T9	8.0 % of Low-Density Polyethylene (LDPE)	576	698	-122	81.25	-1.50

Table 9. Agronomic efficiency of Potassium

Treatments		Treated plot yield	Control yield	Treated yield - control plot yield	K applied to the crop	Agronomic efficiency K
		(kg ha^{-1})				
T1	Absolute control (Without fertilizers and Microplastic)	850	698	152	56.25	2.70
T2	Control (Without Microplastic)	814	698	116	56.25	2.06
T3	0.5 % of Low-Density Polyethylene (LDPE)	704	698	6	56.25	0.10
T4	1.0 % of Low-Density Polyethylene (LDPE)	788	698	90	56.25	1.6
T5	3.0 % of Low-Density Polyethylene (LDPE)	653	698	-45	56.25	-0.8
T6	5.0 % of Low-Density Polyethylene (LDPE)	602	698	-96	56.25	-1.70
T7	7.0 % of Low-Density Polyethylene (LDPE)	588	698	-110	56.25	-1.95
T8	7.5 % of Low-Density Polyethylene (LDPE)	576	698	-122	56.25	-2.16
T9	8.0 % of Low-Density Polyethylene (LDPE)	850	698	152	56.25	2.70

3.3.. Apparent N, P and K recovery

The apparent NPK recovery shows how effectively applied nitrogen, phosphorous, and potassium were absorbed. In this control, nitrogen recovery was high and negative results were observed in treatments with 8%, 7.5%, 7%, and 5% concentration of LDPE. The effectiveness of using nitrogen reduced dramatically as the amount of N fertilizer applied increased **[23].** Phosphorus was not recovered in 1% of the LDPE concentration; control showed a strong recovery of phosphorus, while 8% of the LDPE concentration showed a negative recovery. Only the control and 0.5% concentration of LDPE showed positive recovery in potassium; the other treatments showed negative recovery.

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Table 10. Apparent Recovery of Nitrogen

	Treatments	Uptake of N in particular treatment (Yt)	Uptake of N in unfertilized (Yo)	Quantity of N applied for the treatment (Nt)	Yt-Yo	Yt-Yo / Nt	Apparent N recovery
T1	Absolute control (Without fertilizers and Microplastic)	-	-	-	-	-	-
T2	Control (Without Microplastic)	111	92	87.5	19	0.21	21.71
T3	0.5 % of Low-Density Polyethylene (LDPE)	106	92	87.5	14	0.16	16
T4	1.0 % of Low-Density Polyethylene (LDPE)	97	92	87.5	5	0.05	5.71
T5	3.0 % of Low-Density Polyethylene (LDPE)	95	92	87.5	3	0.03	3.42
T6	5.0 % of Low-Density Polyethylene (LDPE)	88	92	87.5	-4	-0.04	-4.57
T7	7.0 % of Low-Density Polyethylene (LDPE)	85	92	87.5	-7	-0.08	-8
T8	7.5 % of Low-Density Polyethylene (LDPE)	82	92	87.5	-10	-0.11	-11.42
T9	8.0 % of Low-Density Polyethylene (LDPE)	77	92	87.5	-15	-0.17	-17.14

Table 11. Apparent Recovery of Phosphorous

	Treatments	Uptake of P in particular treatment (Yt)	Uptake of P in unfertilized (Yo)	Quantity of P applied for the treatment (Nt)	Yt-Yo	Yt-Yo / Nt	Apparent P recovery
T1	Absolute control (Without fertilizers and Microplastic)	-	-	-	-	-	-
T2	Control (Without Microplastic)	32.4	26.5	81.25	5.9	0.07	7.26
T3	0.5 % of Low-Density Polyethylene (LDPE)	30	26.5	81.25	3.5	0.04	4.30
T4	1.0 % of Low-Density Polyethylene (LDPE)	26.5	26.5	81.25	0	0	0
T5	3.0 % of Low-Density Polyethylene (LDPE)	30.5	26.5	81.25	4	0.04	4.92
T6	5.0 % of Low-Density Polyethylene (LDPE)	23	26.5	81.25	-3.5	-0.04	-4.30
T7	7.0 % of Low-Density Polyethylene (LDPE)	22.5	26.5	81.25	-4	-0.04	-4.92
T8	7.5 % of Low-Density Polyethylene (LDPE)	19.5	26.5	81.25	-7	-0.08	-8.61
T9	8.0 % of Low-Density Polyethylene (LDPE)	15.5	26.5	81.25	-11	-0.13	-13.53

Table 12. Apparent Recovery of Potassium

	Treatments	Uptake of K in particular treatment (Yt)	Uptake of K in unfertilized (Yo)	Quantity of N applied for the treatment (Nt)	Yt-Yo	Yt-Yo / Nt	Apparent K recovery
T1	Absolute control (Without fertilizers and Microplastic)	-	-	-	-	-	-
T2	Control (Without Microplastic)	98	80	56.25	18	0.32	32
T3	0.5 % of Low-Density Polyethylene (LDPE)	89	80	56.25	9	0.16	16
T4	1.0 % of Low-Density Polyethylene (LDPE)	78	80	56.25	-2	-0.03	-3.55
T5	3.0 % of Low-Density Polyethylene (LDPE)	84	80	56.25	4	0.07	7.11
T6	5.0 % of Low-Density Polyethylene (LDPE)	75	80	56.25	-5	-0.08	-8.88
T7	7.0 % of Low-Density Polyethylene (LDPE)	72	80	56.25	-8	-0.14	-14.22
T8	7.5 % of Low-Density Polyethylene (LDPE)	69	80	56.25	-11	-0.19	-19.55
T9	8.0 % of Low-Density Polyethylene (LDPE)	66	80	56.25	-14	-0.24	-24.88

4. CONCLUSION

From the investigation the presence of microplastic LDPE was response for nutrient retention in soil pool indicated by the nutrient balance studies, agronomic efficiency and apparent nutrient recovery for the major nutrients were recorded. Hence it is strongly proven that the chance of entering microplastic in to soil ecosystem and damaging the crop growth. Therefore, more investigation is necessary to clarify the underlying mechanisms causing the changes that have been noticed and to evaluate the long-term effects of LDPE on crop growth, yield, environmental sustainability, and soil health.

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