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Assessing the Nutrient Balance and Nutrient use Efficiency of Various Concentration of Low-Density Polyethylene (LDPE) on Green Gram (*Vigna radiata L. Wilczek*) Cultivation

Gownipalli Chinni Sravya [a++*], K. Udhaya Kumar [a#], Sneha Gautam [b†], R. Isaac Manuel [a‡], R. Susan Poonguzhali [c#], Brundha. A [d^] and M. Govindharaj [e†]

[a] *Division of Agronomy, School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore 641 114, Tamil Nadu, India.*
[b] *Division of Civil Engineering, Karunya Institute of Technology and Sciences, Coimbatore 641 114, Tamil Nadu, India.*
[c] *Division of Soil Science, Karunya Institute of Technology and Sciences, Coimbatore 641 114, Tamil Nadu, India.*
[d] *Department of Agricultural Microbiology, Tamil Nadu Agricultural University, Coimbatore 641 114, Tamil Nadu, India.*
[e] *Department of Seed Science and Technology, Division of Crop Improvement, Adhiyamaan College of Agriculture and Research, Coimbatore 641 114, Tamil Nadu, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] *PG Research Scholar;*
[#] *Assistant Professor;*
[†] *Associate Professor;*
[‡] *Associate Professor and Head;*
[^] *Senior Research Fellow;*
**Corresponding author: E-mail: gownipalli@karunya.edu.in, chinnisravya09@gmail.com;*

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ABSTRACT

The pot experiment was to assessing the nutrient balance and nutrient efficiency of green gram crop under various levels of LDPE incubation conducted in Instructional farm (North), Karunya Institute of Technology and Sciences, Coimbatore**.** The experiment was laid out in Complete Randomized Design (CRD) with nine treatments and three replications. The treatment in the nutrient studies shows negative response in control and in 0.5% concentration of LDPE and has positive response in the remaining treatments, in agronomic efficiency the higher concentration has negative response and Apparent recovery studies shows that nitrogen recovery was high in higher concentration, phosphorous and potassium recovery has negative results in lower concentration.

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. Microplastic studies are wide-ranging and harmful impacts of microplastics on crop growth, soil quality, and agricultural productivity [8]

Microplastics exert a significant influence on soil ecosystems by modifying soil structure, thereby impacting its porosity and water dynamics. This alteration subsequently influences infiltration and retention patterns within the soil. [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]. The objective of the study is to calculate nutrient balance, Agronomic efficiency and Apparent recovery of Nitrogen, Phosphorous and Potassium.

2. MATERIALS 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 10º56'N latitude and 76º44'E longitude at an altitude of 427 m above mean sea level.

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 LDPE
T_4	:	1.0 % of LDPE
T_5	:	3.0 % of LDPE
T_6	:	5.0 % of LDPE
T_7	:	7.0 % of LDPE
T_8	:	7.5 % of LDPE
T_9	:	8.0 % of LDPE

***Note:** LDPE- Low Density Polyethylene*

***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*

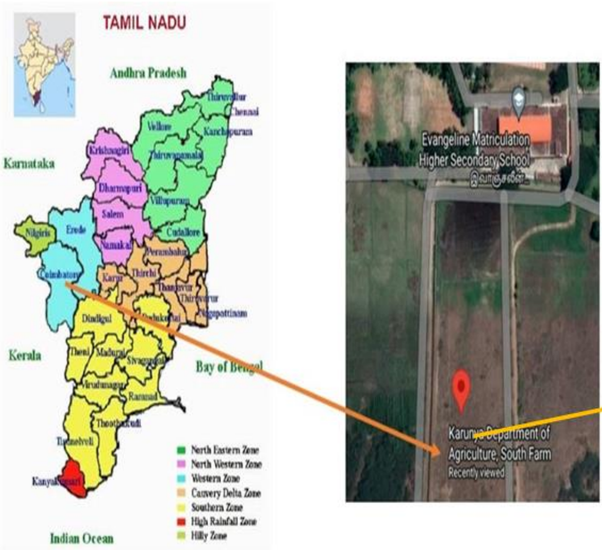

Fig. 1. Map showing study location

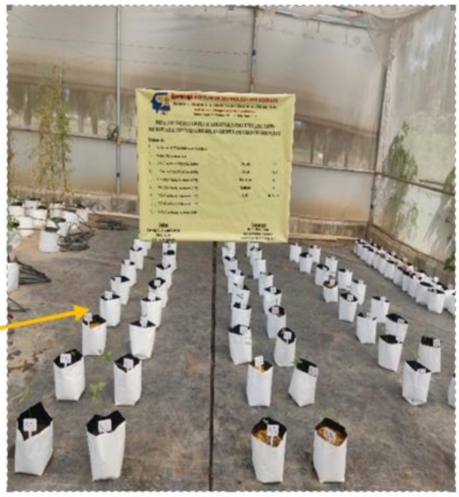

Fig. 2. Pot experiment in polyhouse

Table 2. Initial soil status

Parameters	value	Method	Reference
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 of N, 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)=(per content nutrient content × 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=(Grain yield in fertilized plot (kg /ha) - Grain yield in unfertilized plot(kg /ha))/(Quantity of nutrient applied (kg/ha))

2.8 Apparent Nutrient Recovery

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 obtaining 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. The adverse effects observed in soil due to the presence of LDPE, which accumulates in plant roots, can impair crop growth by diminishing their capacity to absorb water and nutrients from the soil. [20] and indirectly alter the microbiota, nutrients, and soil qualities, potentially negatively influencing crop yield.

Thus, 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.

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 LDPE	260	87.5	97	-9.5	256	-4
T5	3.0 % of LDPE	260	87.5	95	-7.5	259	-1
T6	5.0 % of LDPE	260	87.5	88	-0.5	261	1
T7	7.0 % of LDPE	260	87.5	85	2.5	262	2
T8	7.5 % of LDPE	260	87.5	82	5.5	264	4
T9	8.0 % of 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)	Computed 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 LDPE	8.9	81.25	26.5	54.75	52	43.1
T5	3.0 % of LDPE	8.9	81.25	30.5	50.75	51	42.1
T6	5.0 % of LDPE	8.9	81.25	23	58.25	53	44.1
T7	7.0 % of LDPE	8.9	81.25	22.5	58.75	54	45.1
T8	7.5 % of LDPE	8.9	81.25	19.5	61.75	55	46.1
T9	8.0 % of 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 LDPE	286	56.25	78	-21.75	288	2
T5	3.0 % of LDPE	286	56.25	84	-27.75	286	0
T6	5.0 % of LDPE	286	56.25	75	-18.75	289	3
T7	7.0 % of LDPE	286	56.25	72	-15.75	290	4
T8	7.5 % of LDPE	286	56.25	69	-12.75	291	5
T9	8.0 % of LDPE	286	56.25	66	-9.75	292	6

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 LDPE	814	698	116	87.5	1.32
T4	1.0 % of LDPE	704	698	6	87.5	0.06
T5	3.0 % of LDPE	788	698	90	87.5	1.02
T6	5.0 % of LDPE	653	698	-45	87.5	-0.51
T7	7.0 % of LDPE	602	698	-96	87.5	-1.09
T8	7.5 % of LDPE	588	698	-110	87.5	-1.25
T9	8.0 % of LDPE	576	698	-122	87.5	-1.39

Table 8. Agronomic efficiency of Phosphorous

Treatments		Treated plot yield	Control yield	Treated yield – control plot yield	P applied to the crop	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 LDPE	814	698	116	81.25	1.42
T4	1.0 % of LDPE	704	698	6	81.25	0.07
T5	3.0 % of LDPE	788	698	90	81.25	1.10
T6	5.0 % of LDPE	653	698	-45	81.25	-0.55
T7	7.0 % of LDPE	602	698	-96	81.25	-1.18
T8	7.5 % of LDPE	588	698	-110	81.25	-1.35
T9	8.0 % of 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)	-	-	-	-	-
T2	Control (Without Microplastic)	850	698	152	56.25	2.70
T3	0.5 % of LDPE	814	698	116	56.25	2.06
T4	1.0 % of LDPE	704	698	6	56.25	0.10
T5	3.0 % of LDPE	788	698	90	56.25	1.6
T6	5.0 % of LDPE	653	698	-45	56.25	-0.8
T7	7.0 % of LDPE	602	698	-96	56.25	-1.70
T8	7.5 % of LDPE	588	698	-110	56.25	-1.95
T9	8.0 % of LDPE	576	698	-122	56.25	-2.16

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 [21].

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 [22]. Phosphorus was not recovered in 1% of the LDPE concentration; control showed a strong recovery of phosphorus, while 8% of the

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 LDPE	106	92	87.5	14	0.16	16
T4	1.0 % of LDPE	97	92	87.5	5	0.05	5.71
T5	3.0 % of LDPE	95	92	87.5	3	0.03	3.42
T6	5.0 % of LDPE	88	92	87.5	-4	-0.04	-4.57
T7	7.0 % of LDPE	85	92	87.5	-7	-0.08	-8
T8	7.5 % of LDPE	82	92	87.5	-10	-0.11	-11.42
T9	8.0 % of 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 LDPE	30	26.5	81.25	3.5	0.04	4.30
T4	1.0 % of LDPE	26.5	26.5	81.25	0	0	0
T5	3.0 % of LDPE	30.5	26.5	81.25	4	0.04	4.92
T6	5.0 % of LDPE	23	26.5	81.25	-3.5	-0.04	-4.30
T7	7.0 % of LDPE	22.5	26.5	81.25	-4	-0.04	-4.92
T8	7.5 % of LDPE	19.5	26.5	81.25	-7	-0.08	-8.61
T9	8.0 % of 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 LDPE	89	80	56.25	9	0.16	16
T4	1.0 % of LDPE	78	80	56.25	-2	-0.03	-3.55
T5	3.0 % of LDPE	84	80	56.25	4	0.07	7.11
T6	5.0 % of LDPE	75	80	56.25	-5	-0.08	-8.88
T7	7.0 % of LDPE	72	80	56.25	-8	-0.14	-14.22
T8	7.5 % of LDPE	69	80	56.25	-11	-0.19	-19.55
T9	8.0 % of LDPE	66	80	56.25	-14	-0.24	-24.88

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.

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 into 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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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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