

## Original Research Article

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4 **Carbon and Zeolite based Slow Release Fertilizer Formulations Enhances Nutrient Use Efficiency and Yield in Chilli**

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**ABSTRACT**

**Aims:** To develop slow release fertilizer formulations using humic acid, charcoal and zeolite and to evaluate nutrient availability, nutrient use efficiency and yield in chilli.

**Study design:** This experiment was conducted through completely randomized design with 14 treatments and 3 replications.

**Place and Duration of Study:** The research was appraised at the Department of Soil Science, College of Agriculture, Vellayani between September 2022- December 2022.

**Methods:** Carbon and zeolite based slow release fertilizer formulations (SRF) containing all the major, secondary and micronutrients were prepared using compatible fertilizer materials (urea, rajphos, muriate of potash, phosphogypsum, magnesium sulphate, zinc sulphate and borax), carrier materials (zeolite, humic acid and charcoal) and the binding agent (carboxy methyl cellulose) in the ratio of 1:1 and 1: 0.5 in the form of pellets. These formulations were applied to chilli and evaluated nutrient use efficiency and yield.

**Results:** The pellets were highly stable and weight ranged between 4.0 and 4.5 g. The highest fruit yield of chilli observed was 581.2 g/ plant. The available nitrogen ( $320.86 \text{ kg ha}^{-1}$ ), phosphorus ( $87.15 \text{ kg ha}^{-1}$ ), potassium ( $214.35 \text{ kg ha}^{-1}$ ), calcium ( $351.13 \text{ mg kg}^{-1}$ ), magnesium ( $106.54 \text{ mg kg}^{-1}$ ), sulphur ( $9.32 \text{ mg kg}^{-1}$ ), boron ( $0.46 \text{ mg kg}^{-1}$ ) and zinc ( $4.25 \text{ mg kg}^{-1}$ ) was found to be highest in treatment receiving 75 % recommended dose of fertilizers (RDF) as humic acid based slow release formulation applied in two splits (basal and 1 MAP). The apparent recovery percentage of nitrogen 78.2 %, phosphorus 86.33 % and potassium 98.70 % and partial factor productivity of  $25.98 \text{ g g}^{-1}$  were recorded due to the application of pellets.

**Conclusion:** Carbon and zeolite based slow release fertilizer formulations in the form of pellets are very effective compared to conventional fertilizers due to their gradual pattern of nutrient release which better meets plant demand, minimizes leaching and therefore nutrient use efficiency and ultimately crop yield. Application of slow release formulations significantly increases the nutrient availability in soil, nutrient use

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efficiency, growth and yield of chilli.

## 1. INTRODUCTION

Agriculture is very important for people all over the world for providing food to the massively by increased population. This, in turn, leads to significant rise in fertilizers usage to improve soil fertility and to increase yields. However, the indiscriminate and uncontrolled use of fertilizers contributes not only to the degradation of soil quality but also to the leaching loss of nutrients due to the high solubility of fertilizers. Conventional fertilizers have low nutrient uptake efficiencies and are often associated with high losses to the environment and effects negative consequences. Nutrient use efficiency of fertilizer is very low due to numerous pathways of losses such as leaching, volatilization, denitrification, microbial immobilization and runoff. The key point of crop fertilization is to avoid nutrient losses and synchronize the nutrient availability with its uptake by crop.

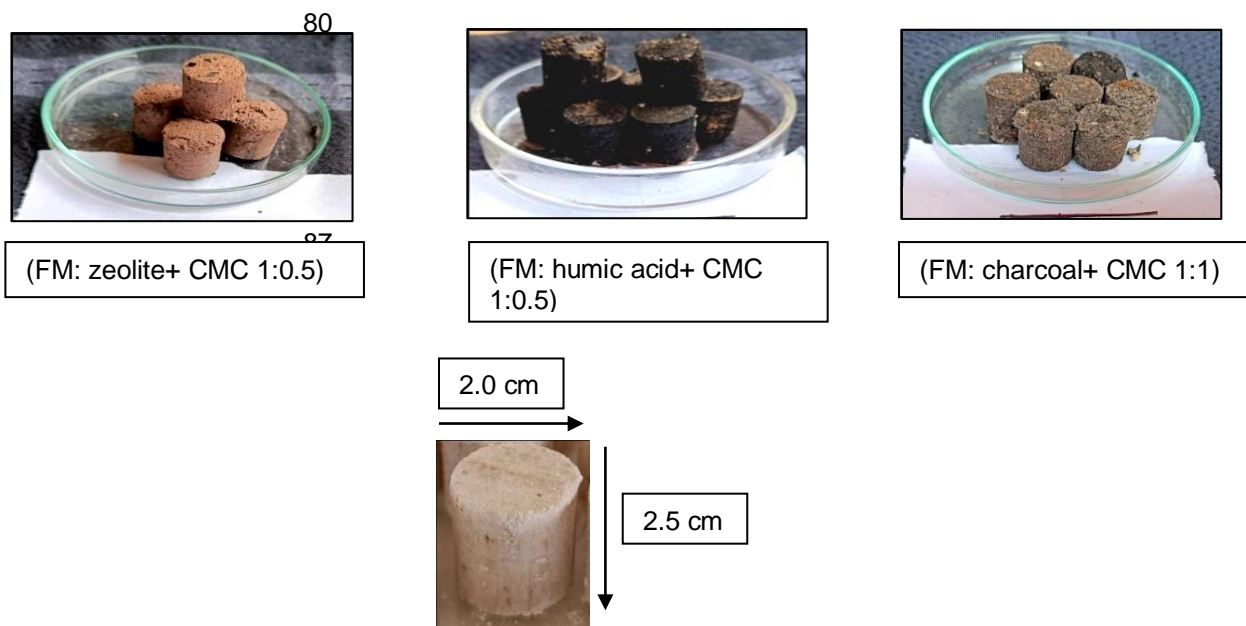
Smart fertilizers based on slow-/controlled-release and/ or carrier delivery system have been shown to improve crop yields, soil productivity and lower nutrient loss compared with conventional fertilizers [1]. Several materials such as clays (zeolite, bentonite, montmorillonite), carbon material like charcoal, biochar and humic acid are suitable for development of smart fertilizers acting as a carrier for nutrients. Most of the common extensively used fertilizers are highly water soluble. When such materials are used in cultivation, particularly in a state like Kerala, where rainfall is well distributed and heavy, only very low efficiency could be expected on account of several losses. Smart fertilizers like slow release fertilizer is the novel technology to enhance the nutrient use efficiency, thereby improving crop yield in sustainable manner.

Therefore, the natural materials such as clay, zeolite, humic acid, charcoal / biochar carbon and their nano sizes are suitable for development of smart fertilizers acting as carrier matrices for nutrients.. Zeolite due to their special crystalline structure, have excellent adsorption, ion exchange and catalytic properties. Zeolite have large surface area and porous and keep nutrients in porous structure and release slowly. They are negatively charged and they adsorb positively charged ions and temporally bind it and slowly release nutrients [2]. The charcoal carbon and humic acid are very strong in capacity of adsorbing and maintaining nutrients and moisture, and furthermore, has an effect of stimulating the growth of crops and a good slow-release performance for the nitrogen, phosphorus and potassium [3]. In the present study natural zeolite, humic acid and charcoal based multi nutrient slow release fertilizers which release nutrients slowly over a longer period of time were developed and evaluated in chilli.

## 2. MATERIAL AND METHODS

### 2.1 Development and Characterization of Slow Release Fertilizer Formulations

Carbon and zeolite based slow release fertilizer formulations containing major, secondary and micro nutrients were prepared using compatible fertilizer sources (urea, rajphos, muriate of potash, phophogypsum, magnesium sulphate, zinc sulphate and borax), carrier materials (zeolite, charcoal and humic acid) and binding agents (carboxy methyl cellulose). Formulations were prepared in the ratio of 1:1 and 1: 0.5 (fertilizer mix: carrier + binding agent). Multinutrient fertilizer mix was prepared with urea (22 g), rajphos (25 g), MOP (6.0 g), Magnesium sulphate (12.0 g), phosphogypsum (25.0 g), zinc sulphate (6.0 g), borax (3.0 g) based on soil nutrient status and crop nutrient requirements. The formulations was prepared in the form of pellets using pelleting machine by compaction process, [4] with 2.5 cm height, 2 cm in diameter and 4 to 4.5 g weight. The pellets prepared are P1 (Fertilizer mix: zeolite+ carboxy methyl cellulose-1:0.5), P2 (Fertilizer mix: humic acid + carboxy methyl cellulose-1:0.5) and P3 (Fertilizer mix: charcoal+ carboxy methyl cellulose- 1:1) (plate. 1). The stability, disintegration time, nutrient content, pH, EC, moisture content and bulk density of these pellets were analysed using standard procedures.

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100 **Plate 1. Prepared slow release fertilizer pellets**

## 101 2.2 Evaluation of Slow Release Formulations in Chilli

102 A pot culture experiment was carried out at College of Agriculture, Vellayani during September 2022 with chilli variety  
 103 Vellayani Athulya as test up to evaluate the effect of these pellets on nutrient availability in soil, nutrient use efficiency,  
 104 growth and yield. Slow release fertilizer formulations were applied at 2 levels viz., 75 and 100 % of recommended dose of  
 105 fertilizers and were compared with package of practice recommendation of Kerala Agricultural University, 2016 and  
 106 absolute control. The design was CRD with 14 treatments and 3 replications. The required quantity of nutrients as per the  
 107 levels of 75 % and 100% of recommended dose of fertilizers for each plant was satisfied with 6 and 8 pellets respectively.  
 108 The pellets were placed at a depth of 5 cm and a distance of 5 cm away from the root zone. The soil samples collected  
 109 from the pot experiment were analysed for pH, EC, organic carbon, nutrients such as N, P, K, Ca, Mg, S, Zn and B **as per**  
 110 **standard procedures**. The biometric observations viz., plant height, number of fruits per plant and yield were recorded.  
 111 The results of various parameters obtained from experiments were analysed statistically for the test of significance by  
 112 standard procedures using GRAPES software.

## 113 3. RESULTS AND DISCUSSION

### 114 3.1 Pellet Characterization

#### 115 3.1.1 Properties of slow release fertilizer pellets

116 Properties of slow release fertilizer pellets (Table 1) revealed that the pellets prepared were hard and highly stable, their  
 117 disintegration time varied from 10 to 11 hours and were non hygroscopic. The pH was found to be acidic (6.4 to 6.59). The  
 118 acidic nature of slow release formulation might be due to the presence of acidic ions. [5] observed that the pH of leachate  
 119 from controlled release fertilizers was found to be variable but constantly acidic this might be due to the influence of  
 120 fertilizers used. Electrical conductivity varied between 18.45 (P3) to 23.10 dS m<sup>-1</sup>(P1). This might be attributed to the  
 121 presence of soluble salts in the formulations from fertilizers used. An increased in electrical conductivity of leachates from  
 122 controlled release fertilizers is reported by [5] due to the release of dissolved salts from the fertilizers. The moisture  
 123 content of the pellets ranged from 8.61% (P1) to 7.35 % (P3). The bulk density varied between 0.53 and 0.57 Mg m<sup>-3</sup>.

#### 124 3.1.2 Nutrient content of pellets

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Nutrient content in the pellets are depicted in the Table 2. The pellet contains 8.38 to 8.63 % nitrogen, 5.36 to 5.84% phosphorus, 3.31 to 3.41 % potassium, 5.40 to 5.62 % calcium, 2.01 to 2.75 % magnesium, 4.20 to 5.20 % sulphur, 0.17 to 0.23% boron and 1.2 to 1.5 % zinc. The highest concentration of nitrogen was recorded in P2 (8.63 %), this might be due to presence of high nitrogen content in humic acid used in the formulation. Similar results were reported by [6] in a multinutrient fertilizer tablets which contained 8.42 % nitrogen, 4.67 % phosphorus and 2.43 % potassium content. Phosphorus content was highest in P1 (5.84 %) which might be contributed from zeolite used which contained about 2.54 % phosphorus.

**Table 1. Properties of slow release fertilizer pellets**

Pellets	Stability	Disintegration time (hours)	Hygroscopicity	pH	EC (dS m <sup>-1</sup> )	Moisture content (%)	BD (Mg m <sup>-3</sup> )
P1	Highly stable	11	Nil	6.40	23.10	8.61	0.57
P2	Highly stable	10	Nil	6.48	20.15	7.20	0.53
P3	Highly stable	10	Nil	6.59	18.45	7.35	0.57

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\*P1 (Fertilizer mix: zeolite+ carboxy methyl cellulose-1:0.5), P2 (Fertilizer mix: humic acid + carboxy methyl cellulose-1:0.5) and P3 (Fertilizer mix: charcoal+ carboxy methyl cellulose- 1:1).  
BD- Bulk density

**Table 2. Nutrient content in slow release fertilizer pellets**

Pellets	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (%)	B (%)
P1	8.38	5.84	3.31	5.62	2.75	5.20	1.5	0.23
P2	8.63	5.66	3.40	5.68	2.86	5.30	1.6	0.22
P3	8.42	5.36	3.41	5.40	2.01	4.20	1.2	0.17

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## 3.2 Evaluation of Slow Release Formulations in Chilli

### 3.2.1 Nutrient availability in soil

The available nutrients in soil were significantly influenced by the application of different slow release fertilizer formulations (Table 3). The available nitrogen (320.86 kg ha<sup>-1</sup>), phosphorus (87.15 kg ha<sup>-1</sup>), potassium (214.35 kg ha<sup>-1</sup>), calcium (351.13 mg kg<sup>-1</sup>), magnesium (106.54 mg kg<sup>-1</sup>), sulphur (9.32 mg kg<sup>-1</sup>), boron (0.46 mg kg<sup>-1</sup>) and zinc (4.25 mg kg<sup>-1</sup>) was found to be the highest in treatment T<sub>3</sub> receiving 100 % recommended dose of fertilizers as slow release containing FM : HA+CMC in the ratio 1:0.5, which was followed by T<sub>6</sub> receiving 100% of RDF as slow release fertilizer formulation applied in two splits (basal&1 MAP) both were found to be on par. This might be due to the gradual release of nutrients from the pellets and also to the nutrient content and adsorption capacity of carriers that gradually increased the availability in soil [7, 8, 9]. [10] reported that soil available nutrients was increased by the application of zeolite based slow release fertilizer.

**Table 3. Effect of slow release fertilizer formulations on nutrient availability in soil**

Treatment	N (kg ha <sup>-1</sup> )	P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )	K <sub>2</sub> O (kg ha <sup>-1</sup> )	Ca (mg kg <sup>-1</sup> )	Mg (mg kg <sup>-1</sup> )	S (mg kg <sup>-1</sup> )	Zn (mg kg <sup>-1</sup> )	B (mg kg <sup>-1</sup> )
T <sub>1</sub>	304.4	78.34	192.3	302.2	99.85	6.45	4.02	0.39
T <sub>2</sub>	317.7	84.11	210.5	342.1	104.1	7.69	4.15	0.42
T <sub>3</sub>	303.5	76.03	190.5	301.1	98.42	5.91	3.97	0.37
T <sub>4</sub>	314.3	82.53	209.0	325.1	103.5	7.45	4.12	0.41

170	T <sub>5</sub>	311.9	81.45	206.8	320.3	102.7	7.21	4.09	0.40
171	T <sub>6</sub>	318.1	85.66	213.4	346.0	105.0	8.53	4.21	0.44
172	T <sub>7</sub>	308.3	81.00	205.4	317.5	101.6	6.86	4.05	0.40
174	T <sub>8</sub>	320.8	87.15	214.3	351.1	106.5	9.32	4.25	0.46
175	T <sub>9</sub>	286.8	69.19	177.0	282.1	96.09	5.55	3.92	0.30
176	T <sub>10</sub>	295.4	71.22	181.9	296.4	98.00	5.83	3.85	0.34
178	T <sub>11</sub>	254.7	69.01	176.8	276.2	96.00	5.41	3.90	0.31
179	T <sub>12</sub>	297.2	73.59	185.7	297.5	98.00	6.42	3.95	0.35
180	T <sub>13</sub>	307.3	80.11	205.6	303.8	99.10	5.16	3.87	0.29
181	T <sub>14</sub>	165.6	51.12	80.10	210.0	42.58	2.12	1.00	0.11
183	SEm (±)	8.51	1.99	6.33	1.88	1.89	0.08	0.05	0.02
184	*T <sub>1</sub> CD(0.05)	24.53	5.97	18.92	14.47	5.489	0.24	0.13	0.05

185 (100% RDF as FM:Z+CMC-1:0.5 applied as basal), T<sub>2</sub> (100% RDF as FM:Z+CMC-1:0.5 applied in two splits (basal & 1  
 186 MAP), T<sub>3</sub> (75% RDF as FM:Z+CMC-1:0.5 applied as basal), T<sub>4</sub> (75% RDF as FM:Z+CMC-1:0.5 applied in two splits (basal  
 187 & 1 MAP), T<sub>5</sub> (100% RDF as FM:HA+CMC-1:0.5 applied as basal), T<sub>6</sub> (100% RDF as FM:HA+CMC-1:0.5 applied in two  
 188 splits (basal & 1 MAP), T<sub>7</sub> (75% RDF as FM:HA+CMC-1:0.5 applied as basal), T<sub>8</sub> (75% RDF as FM:HA+CMC-1:0.5  
 189 applied in two splits (basal & 1 MAP), T<sub>9</sub> (100% RDF as FM:CHAR+CMC-1:1 applied as basal), T<sub>10</sub> (100% RDF as  
 190 FM:CHAR+CMC-1:1 applied in two splits (basal & 1 MAP), T<sub>11</sub> —75% RDF as FM:CHAR+CMC-1:1 applied as basal), T<sub>12</sub>  
 191 (75% RDF as FM:CHAR+CMC-1:1 applied in two splits (basal & 1 MAP), T<sub>13</sub> (Soil test based KAU POP  
 192 recommendation), T<sub>14</sub> (Control).

### 194 3.2.2 Growth and yield parameters

196 The growth and yield of chilli was significantly influenced due to the application of slow release fertilizer  
 197 formulations (Table 3). The maximum plant height (56.52 cm) and number of fruits per plant (52.70) were obtained from  
 198 the treatment T<sub>8</sub> receiving 75 % of recommended dose of fertilizers as slow release fertilizer formulation  
 199 FM:HA+CMC(1:0.5 ) applied in two splits (basal & 1MAP). The maximum yield of 581.2 g per plant was also recorded in  
 200 the same treatment which was on par with T6 receiving 100% RDF as FM:HA+CMC-1:0.5 applied in two splits (basal & 1  
 201 MAP (506.5 g per plant) and were found to be significantly superior over all other treatments. The yield and yield  
 202 attributes was significantly influenced by the slow release fertilizer formulations due to the higher nutrient use efficiency  
 203 and plant growth [11]. [12] reported highest growth in maize by using humic acid based slow release fertilizer. The effect  
 204 of humic acid multinutrient fertilizers on growth parameters of potato was reported by [13]. Highest yield were also  
 205 reported in apple [14], soybean [15] and [16] due to application of humic acid multinutrient complex fertilizers.

207 **Table 4. Effect of slow release fertilizer formulations on growth and yield in chilli**

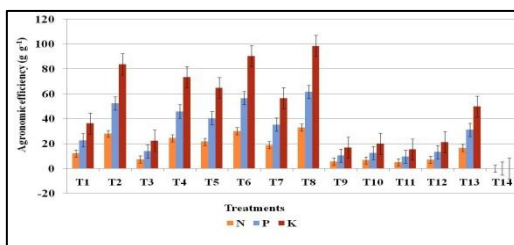
Treatments	Plant height (cm)	Number of fruits per plant	Yield (g per plant)
T <sub>1</sub>	44.57	33.69	261.7
T <sub>2</sub>	51.65	44.60	469.1
T <sub>3</sub>	43.76	33.15	211.8
T <sub>4</sub>	49.29	42.13	450.7
T <sub>5</sub>	47.29	39.65	372.3
T <sub>6</sub>	53.14	46.64	506.5
T <sub>7</sub>	46.40	37.69	343.3
T <sub>8</sub>	56.52	52.70	581.2

T <sub>9</sub>	42.56	30.66	165.8
T <sub>10</sub>	42.76	31.14	178.7
T <sub>11</sub>	41.48	29.87	153.5
T <sub>12</sub>	43.14	32.59	199.1
T <sub>13</sub>	44.92	35.58	314.8
T <sub>14</sub>	37.88	26.24	124.64
SEm (±)	1.15	0.86	15.10
CD(0.05)	3.333	2.59	45.31

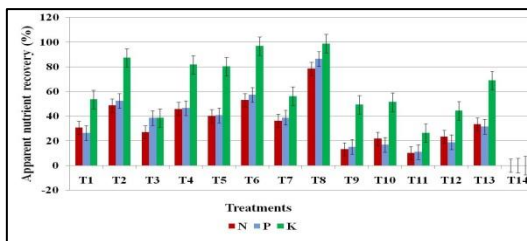
209 \*T<sub>1</sub> (100% RDF as FM:Z+CMC-1:0.5 applied as basal), T<sub>2</sub> (100% RDF as FM:Z+CMC-1:0.5 applied in two splits (basal &  
 210 1 MAP), T<sub>3</sub> (75% RDF as FM:Z+CMC-1:0.5 applied as basal), T<sub>4</sub> (75% RDF as FM:Z+CMC-1:0.5 applied in two splits  
 211 (basal & 1 MAP), T<sub>5</sub> (100% RDF as FM:HA+CMC-1:0.5 applied as basal), T<sub>6</sub> (100% RDF as FM:HA+CMC-1:0.5 applied in  
 212 two splits (basal & 1 MAP), T<sub>7</sub> (75% RDF as FM:HA+CMC-1:0.5 applied as basal), T<sub>8</sub> (75% RDF as FM:HA+CMC-1:0.5  
 213 applied in two splits (basal & 1 MAP), T<sub>9</sub> (100% RDF as FM:CHAR+CMC-1:1 applied as basal), T<sub>10</sub> (100% RDF as  
 214 FM:CHAR+CMC-1:1 applied in two splits (basal & 1 MAP), T<sub>11</sub>—75% RDF as FM:CHAR+CMC-1:1 applied as basal), T<sub>12</sub>  
 215 (75% RDF as FM:CHAR+CMC-1:1 applied in two splits (basal & 1 MAP), T<sub>13</sub> (Soil test based KAU POP  
 216 recommendation), T<sub>14</sub> (Control).  
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218 **3.2.3 Nutrient use efficiency**  
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220 The nutrient use efficiency of slow release fertilizer formulations are given in figure 1 and 2. The treatment T<sub>8</sub> receiving  
 221 75% of recommended dose of fertilizers as slow release fertilizer formulation FM:HA+CMC-1:0.5 applied in two splits  
 222 (basal+1MAP) recorded the highest agronomic efficiency for nitrogen (32.86 g g<sup>-1</sup>), phosphorus (61.61 g g<sup>-1</sup>) and  
 223 potassium (98.58 g g<sup>-1</sup>) which was found to be on par with T<sub>6</sub>. With respect to apparent nutrient recovery the highest  
 224 recovery percentage was recorded by T<sub>6</sub> for N (78.2 %), P (86.33 %) and K (98.70 %). Application of slow release fertilizer  
 225 formulations in the form of pellets might have enhanced the nutrient use efficiencies due to the high adsorption and  
 226 sustained release capacity of carrier materials used [13, 17, 18].  
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 232 **Fig 1. Effect of slow release fertilizer formulation on agronomic efficiency**



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 239 **Fig 2. Effect of slow release fertilizer formulation on apparent recovery**

240 **4. CONCLUSION**  
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242 Carbon and zeolite based slow release fertilizer formulations in the form of pellets are very effective compared to  
 243 conventional fertilizers due to their gradual release pattern of nutrients which better meets plant demand, minimizes

244 leaching and therefore fertilizer use efficiency and ultimately crop yield. Application of slow release formulations prepared  
245 with fertilizer mix: humic acid + CMC in the ratio 1:0.5 significantly increased the nutrient availability in soil, NUE, growth  
246 and yield of chilli.  
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