Current Research in Soil Fertility

Volume - 5

Chief Editor

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Scientist-D, P-4, Tasar Silkworm Breeding Station, Central Silk Board,
Ministry of Textiles, Government of India, Chakradharpur, West Singhbhum
District, Jharkhand, India

AkiNik Publications
New Delhi

Published By: AkiNik Publications

AkiNik Publications
169, C-11, Sector - 3,
Rohini, Delhi-110085, India
Toll Free (India) – 18001234070
Phone No. – 9711224068, 9911215212
Email – akinikbooks@gmail.com

Chief Editor: Dr. Ram Lakhan Ram

Publication Year: 2021

Pages: 110

ISBN: 978-93-91216-77-1

Book DOI: https://doi.org/10.22271/ed.book.1255

Price: ₹ 730-

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Chapter - 1

Co-Composting Process: A Study for Reducing C/N ratio and Assessment Quality of Compost Product via Measurement of Phytotoxicity by Different Feedstock Mixtures

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Abstract

Co-composting is a method for utilized organic waste for agriculture sectors. C/N ratio and feedstock mixtures are mainly for successful on composting process. Coffee husk has high C/N ratio 105.21. Insufficient C/N ratio would be adjusted by accumulation extra material such as animal manure and organic waste for easy nutrient from organic waste absorb into the soil and plant. The present study was conducted in laboratory with aimed to reducing C/N ratio by aerobic co-composting process and enhancing quality of coffee husk, also assessment the quality of co-compost via measurement of phytotoxicity by germination index. Two piles were conducted by mixing coffee husk, chicken manure, and cow dung (Pile. 1) and coffee husk, chicken manure, cow dung, and rice grain (Pile. 2). Samples were collected in 0, 7, 14, 21, 70, and 84 days for analyzed C/N ratio, while in every 7 days for measured pH and EC (electrical conductivity). In addition, initial and in the end of co-composting product was analyzed; NH_4^+, NO3-, total nitrogen, total phosphorus, total cations (K, Ca, Mg), while for germination index was analyzed after co-composting process. The results showed that (Pile. 2) the greatest reduction in C/N ratio with 14.32 ± 0.2 and highest germination index (GI) for Komatsuna *(Brassica rapa* var. *Perviridis*) with 131.5%. Thus, this indicated higher value of total nitrogen which caused by added rice grain to the co-composting pile.

Keywords: coffee husk, co-composting, phytotoxicity, C/N ratio, germination index

Introduction

Production of coffee in the world recorded 761.1 million bags (60 kilograms) in 2019 (USDA, 2020). It is estimated are that about 380.55 million bags (60 kilograms) of coffee husk since 50% produced 1 kg of coffee bean (Zoca *et al*., 2014). Coffee husk is the dried skin of coffee bean is most likely the major remains from processing of coffee. It is important deliberation that these waste might be contributed to environmental problems are toxic in nature which some people living around the coffee plantation and industry.

Composting is a method for decayed organic waste. It is a technique of attaining a nutrient product and as an alternative to improving soil health also killing pathogen which inhibit to growth of plants. Elseways, composting is an approach environmental friendly option organic waste treatment for utilized in agriculture sectors and also as nutrient sources for crop production (Raj and Antil, 2011).

C/N ratio and feedstock mixtures are mainly for successful on composting process (Gao *et al*., 2010). Coffee husk has high C/N ratio with 105.21 (Harada H *et al*., 2020; Endar *et al*., 2020). If value of C/N ratio is higher, it would be make the composting process is very slow caused microorganisms need more nitrogen as nutrient source for degradable of organic material also indicates lower nitrogen which the nutrient might be important for improving and absorb into the soil and plant. In contrast, if low of C/N ratio will be increased loss of nitrogen due to ammonia volatilization (Antil *et al*., 2014). Hence, insufficient C/N ratio would be adjusted by adding another material such as animal manure and organic waste to get suitable in soil also easy absorb nutrient to the plant.

This study was carried out coffee husk was added with cow dung, chicken manure, and rice grain to compost pile. If more than two (2) types of organic waste in compost is called co-composting process (Petric *et al*., 2012) which have advantage for enhancing of compost quality including macro-micro nutrients and reducing C/N ratio during co-composting periods by aerobic condition. Aerobic is breakdown of organic matter that require oxygen for helping microorganisms in degradable of organic waste. Before using in field, the maturity has be assessed since it might seriously affect in soil health and plant growth due to the attendance of pathogenic microorganisms (Gazi *et al*., 2007). Immature compost is applied which might be residue toxic to land and environment (Hu *et al*., 2008). The present study aimed to reducing C/N ratio and enhancing quality of coffee husk, also assessment the value of co-compost via measurement of phytotoxicity by germination index.

Materials and methods

Treatments and co-composting method

Two piles were prepared by mixing rice grain, chicken manure, cow dung and coffee husk was followed (Endar *et al.*, 2020) as shown in (Table 1), taking into account their C/N ratio.

Table 1: Raw Materials

Treatments	RG (g)	CM (g)	CD (g)	CH (g)
Pile. 1	-	50	50	100
Pile. 2	25	50	50	100

RG: rice grain, CM: chicken manure, CD: cow dung, CH: coffee husk.

The co-composting process was performed in laboratory conditions. The materials were passed through a 4.75 m/m sieve and put in plastic box piles was followed (Endar *et al*., 2020) at a small co-composting with same size as in this study. The co-composting process was conducted for 84 days by aerobic condition. The materials were periodically mixed using a spoon to obtain homogeneity and aeration.

Elemental analysis of compost properties

Elemental characteristics of materials used for co-composting has been shown in (Table 2). The pH and EC (electrical conductivity) were observed once per week during co-composting process. The samples were measured using a suspension of 1:5 as followed (Jones *et al*., 2011) were used IAQUA twin-pH-22B and IAQUA twin-EC-33B. Moisture content was following (AOAC, 2002) as given in Eq 1.

$$Moisture\ content\ (\%) = \frac{\text{Initial weight} - \text{Final weight}}{\text{Inital weight}} x\ 100 \qquad \dots (1)$$

NH_4-N and NO_3-N were following (Houba *et al*., 1995). Total P was determined by spectrophotometry 880 nm. 1 gr sample added 10 mL potassium peroxodisulfate and 50 mL distilled water. Heat for 30 minutes in an autoclave at 121 ^oC. After cooling, 25 mL supernatant of sample mixed with 2 mL $C_6H_8O_6$, $(NH_4)_6MO_7O_{24}.4H_2O$, and H_2SO4 (Pai *et al*., 1990). Total cations (K, Ca, Mg) were measured by Aqua-regia digestion method by Atomic Absorption Spectrophotometer (AA-6300) Shimadzu, Japan. 1 g of sample was treated HCL and HNO_3 (ratio 3:1) (Fabunmi *et al*., 2014). Total carbon and total nitrogen were analyzed with an autoanalyzer Macro Corder-MT 6.

Phytotoxicity

Toxic is collective complications in immature fertilizer including compost (Itävaara *et al*., 2002). Phytotoxicity is an essential analysis to check the quality of compost before applied to plant growth. The method used by petri dish. Compost was prepared with ratio 1:10 (fresh compost: water), shaken for 1 h then centrifuged at 5000 rpm for 20 minutes (Harada H *et al*., 2020). Each petri dish distributed 5 seeds with 5 ml of compost extract for 3 days in dark condition in room temperature. This study we used Komatsuna *(Brassica rapa* var. *Perviridis)* and Radish (*Raphanus sativus*). Control was filled with distilled water. After experiment was observed; germination of seed in Eq (2), relative seed germination (SG) in Eq (3), relative root elongation (RE) in Eq (4), germination index in Eq (GI) (5), and vigour index in Eq (6) were estimated by (Amita, 2015) with calculated:

$$Germination\ (\%) = \frac{\text{A}}{\text{B}} x\ 100 \qquad \ldots (2)$$

Where A is germinated seeds, B is total seeds.

$$SG\ (\%) = \frac{\text{seeds germinated in compost−extract}}{\text{seeds germinated in control (distilled water)}} x\ 100 \qquad \ldots (3)$$

$$RE\ (\%) = \frac{\text{Average length of root in extract}}{\text{Average length root in control}} x\ 100 \qquad \ldots (4)$$

$$GI\ (\%) = \frac{\text{Relative seed germination \% x Relative root elongation \%}}{100} \qquad \ldots (5)$$

$$Vigour\ Index = \text{Average length of seedlings \% x germination \%} \qquad \ldots (6)$$

Results and discussion

Coffee husk has high C/N ratio, this is indicated that lower has lower nitrogen content which it can inhibited of plant growth because the C/N ratio appropriate for plant growth <25. The variations in the physicochemical characteristics of all pile during the compost are presented in (Table 3). The value of pH at the beginning were all similar and within the alkaline range. This suggests that the contribution of raw materials to this parameters is strong. Total phosphorus content of all pile increased from initial to the end of co-composting might be caused the nutrient content of the compost pile of the preliminary substance such as amino acids, lignocellulose, microorganisms, feedstock mixtures, stability, and maturity interaction in each other within the composted materials during co-composting process (Dadi *et al*., 2019). The final total cations (Ca, Mg, K) of all pile which in the range of quality compost standard.

Table 2: Elemental characteristics of materials used for co-composting

Parameters*	RG	CM	CD	CH
pH	6.27	6.48	6.43	5.98
EC (mS cm^{-1})	15.67	13.47	10.81	0.9
NH_4-N (mg/L)	21.2	14.4	8.3	2.9
NO_3-N (mg/L)	29.8	15.8	11.5	4.5
NH_4-N : NO_3-N Ratio	0.71	0.91	0.72	0.64
Total Carbon (%)	43.42	19.36	29.55	46.26
Total Nitrogen (%)	2.23	2.15	2.39	0.43
C:N ratio	19.4	9	12	105.21
Phosphorus (%)	0.14	0.13	0.18	0.23

Table 2: Elemental characteristics of materials. *(Harada H *et al.*, 2020; Endar *et al.*, 2020), RG: rice grain, CM: chicken manure, CD: cow dung, CH: coffee husk, EC: Electrical conductivity.

Table 3: Elemental analysis initial and after co-composting

Parameter	Treatment				Compost Standard
	Pile. 1		Pile. 2		
	Initial	After	Initial	After	
pH	8.06 ± 0.54	6.61 ± 0.4	7.23 ± 0.08	6.25 ± 0.5	$5.5\text{-}8.5^{a}$
EC (ms/cm)	4.98 ± 1.34	4.57 ± 0.6	6.16 ± 0.07	8.21 ± 0.5	$2.19\text{-}9.32^{b}$
NH_4-N (mg/L)	31.50 ± 0.71	43 ± 4.38	66.67 ± 5.86	29.5 ± 0.71	$\leq 200^{c}$
NO_3-N (mg/L)	5.67 ± 0.93	21.85 ± 2.33	10.87 ± 1.18	22.15 ± 3.04	$\leq 240^{d}$
NH_4-N : NO_3-N	5.55	1.97	6.13	1.33	$\leq 3.0^{e}$
Total Nitrogen (%)	0.85 ± 0.03	1.8 ± 0.09	1.13 ± 0.03	2.67 ± 0.02	$\geq 1^{f}$
C: N ratio	33.03 ± 1.98	22.31 ± 1.5	21.99 ± 0.79	14.32 ± 0.2	$\leq 25^{g}$
Phosphorus (%)	0.24 ± 0.05	0.36 ± 0.19	0.09 ± 0.03	0.34 ± 0.28	$\geq 0.10^{h}$
Potassium (%)	0.55 ± 0.15	0.62 ± 0.17	0.52 ± 0.14	0.60 ± 0.10	$\geq 0.20^{i}$
Calcium (%)	0.05 ± 0.02	0.06 ± 0.01	0.03 ± 0.02	0.10 ± 0.07	$\leq 25.50^{j}$
Magnesium (%)	0.09 ± 0.04	0.11 ± 0.03	0.07 ± 0.02	0.13 ± 0.05	$\leq 0.60^{k}$

Table 3: Summary of the characteristic's nutrient at the final of co-composting, in assessment with guidelines for sufficient quality of compost. (Mean ± S.D.) EC: electrical conductivity. a. (HKORC, 2005), b. (Yusuf, 2008), c, d. (Barker, 1997), e. (William and Brinton, 2000), f. (Cheng *et al.*, 2013), g. (WERL 2005), H.I.J.K (SNI 19-7030-2004).

pH Scale

The pH is not a main aspect for co-composting considering another materials are in this range of pH. The pH values both of compost pile increased from day 1 to days 7 (Fig. 1). The increase pH value indicates organic material was decomposed then inside to compost medium and ammonium was made (Harada H *et al*., 2020). The characteristic of the ammonium is alkaline (Seyede *et al*., 2014). Afterward from days 7 to days 28 the pH values decreased, this is caused formation of carbon dioxide gas and organic acid during co-composting (Bustamante *et al*., 2014) and might be caused the accretion of organic acids from microbial metabolism or from the production of humic acids and fulvic acids along co-composting process (Albanell *et al*., 1988), also indicate as intermediate products (Beck-Friis *et al*., 2001).

From days 28 until days 49 the pH values both of compost piles increased. This occurred might cause the establishment of NH_3 from the mineralization of amino acids comes from the feedstock mixtures and showed hustle of microorganisms for degradation of organic matter. At the end of the co-composting process the value of pH both of piles were neutral condition, which shows that the compost on the maturity process and nitrification process was occurred (Bustamante *et al*., 2014) leads the nitrate (NO_3) values increased (Butler *et al*., 2001). The value of pH in the final co-composting process were 6.6 and 6.2 (pile. 1 and pile. 2 respectively). This value is ideal for maturity compost are between 5.5 and 8.5 (HKORC 2005).

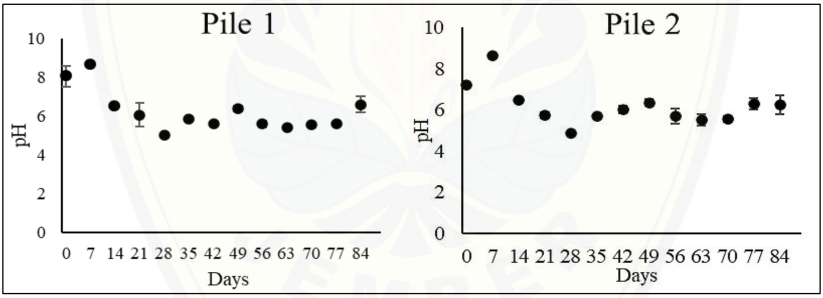

Fig 1: The pH during co-composting (mean ± S.D.)

Electrical conductivity (EC)

The EC indicates as capacity phytotoxicity (immature) on plant growth, also as parameter of the degree of compost salinity (Gao *et al*., 2010). However, the value of EC depends on the degree of organic matter decomposition which leads to accretion of different ionic species in compost pile (Chan *et al*., 2016). As shown in (Fig. 2) (Pile. 1) showed decline from initial to the end of co-composting process. In contrast, (Pile. 2) increased from 6.16 to 8.21ms cm^{-1} which might be due to added rice grain to compost pile as indicated salt source.

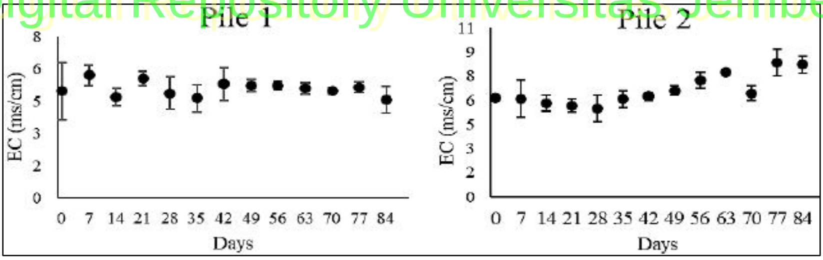

Fig 2: Changes of electrical conductivity (EC) during co-composting (mean ± S.D.)

If mineral salts is higher, it might indicates gradual mineralization of organic material and the discharge into the medium. The high of salinity in compost which can damage to plant roots, influenced to nutrient uptake, also inhibit to seed germination. The EC values of the final both of compost were 4.57 ± 0.6 mS cm^{-1} and 8.21 ± 0.5 mS cm^{-1} (pile. 1 and pile. 2, respectively) as shown in (Table 2). If the value of EC below 9.32 mS cm^{-1} which is indicated safely applied to plant growth.

C/N ratio

The main purpose of co-composting is to reducing carbon to obtaining a C/N ratio ideal for favorable microorganisms also suitable to soil and plant. However, Initial of C/N ratio in co-compost also affect the value of mature products (Huang *et al*., 2004) also a factor indicating the metabolism process which might include enzymatic movement by microorganisms during co-composting process. (Table 2) showed that initial C/N ratio both of pile are 33.03 ± 1.98 and 21.19 ± 0.79 (pile. 1 and pile. 2, respectively). This value is agree in literature that the suitable of initial C/N ratio for compost from 20 to 40 (Neklyudov *et al*., 2008). C/N ratio is one of the main factors influence the value of final co-compost, if ratio is (>40) the co-composting process is making slow which due to there is an excess of degradable carbon for the microorganisms, while if the ratio is (<20) indicate an over of nitrogen which may be out from the process (Antil *et al*., 2014).

The C/N ratio both of compost pile showed significant linear negative correlation (R2 = 0.8998, and R2 = 0.9849) (pile. 1 and pile. 2 respectively) as shown in (Fig. 3). The decline of C/N ratio along of co-composting process which shows constant product (Dadi *et al*., 2019). Similar results were described a decline of C/N ratio by (Shemekite *et al*., 2014). The end value of C/N ratio were suggestion of compost stability and maturity, and they were between 22.31 ± 1.5 and 14.32 ± 0.2 (pile. 1 and pile. 2, respectively). Pile. 2 showed the lowest value compared with pile. 1, which might be due to added of rice grain to compost material also indicate of the degradation of organic carbon (Zhu, 2007). However, the value of C/N ratio both of pile were ideal in compost quality standard which range <25 (WERL, 2005). If the value of C/N ratio compost is higher (>25) are used, carbon content in compost continue to break and assimilated into the soil and microorganisms have bear to use nitrogen (Huang *et al.*, 2004) which occurred immobilization of nitrogen and poor nitrogen also indicated immature compost (TMECC, 2002).

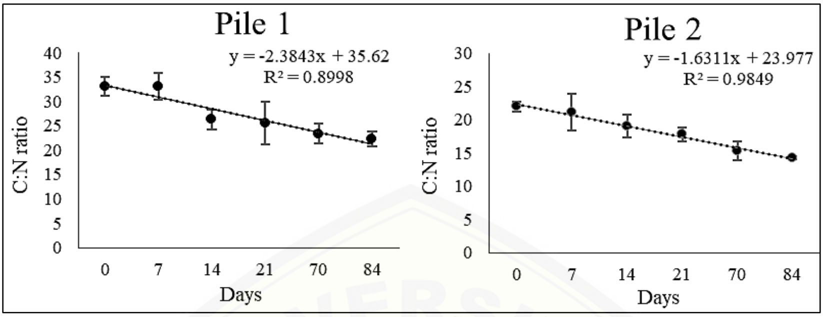

Fig 3: Exponential correlations of carbon to nitrogen ratio during co-composting (mean ± S.D.)

Nitrogen (N)

Nitrogen is a significant indicator of the fertilizer efficiency of compost products. As shown in (Fig. 4) both of compost pile had significant linear correlation from initial to the end of co-composting process (R2 = 0.5928 and R2 = 0.7243) respectively. The increase nitrogen content along the co-composting process might be caused performed of bacteria fixation nitrogen (Nattipong and Alissara, 2006). In final of co-composting process, pile. 1 and pile. 2 contained higher nitrogen content (1.8% and 2.67% respectively). Pile. 2 had a high value when compared pile. 1. This might be caused rice grain added to the compost pile as source nitrogen. Both of compost pile is suitable with the value of compost standard which range >1 and also indicating the co-compost product could be applying to agricultural sectors (Cheng *et al.*, 2013).

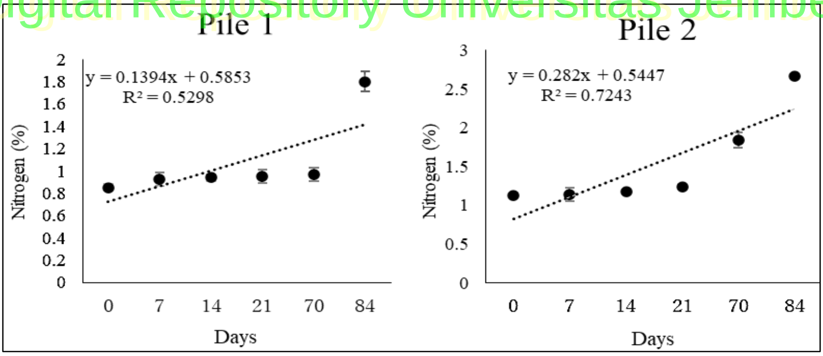

Fig 4: Exponential correlations of total nitrogen ratio during co-composting (mean ± S.D.)

Phytotoxicity

The attendance of toxic in the compost would lead dangerous for use which have response on seed and plant root length cause incomplete melting of organic matter in compost such as phenolic group, organic acid group (Tiquia *et al*., 1996). Maturity of compost can be assessment in many approaches such as by detection on C/N ratio, and germination index (GI) (Yang and Chang, 1998). However, germination index (GI) is easy method for measuring phytotoxicity in compost.

Table 4: Effect of co-composting of coffee husk on seedlings, germination and vigour of Komatsuna *(Brassica rapa* var. *Perviridis*) and Radish (*Raphanus sativus*)

Parameter	Pile. 1		Pile. 2	
	Komatsuna	Radish	Komatsuna	Radish
Germination (%)	80	93.3	93.3	93.3
Seed germinated (%)	120	116.7	140	116.7
Relative root Elongation (%)	99.5	88.8	93.9	79.0
Germination Index (%)	119.4	103.6	131.5	92.2
Average length (cm)	2.7	1.8	2.8	1.8
Vigour Index	327.2	200.5	366.2	168.6

Table 4. Effect of co-composting on seedlings, germination and vigour of Komatsuna.

The present study, we conducted two kind of plant seedling Komatsuna (*Brassica rapa* var. *Perviridis*) and Radish *(Raphanus sativus*) for detected of phytotoxicity of co-compost has been shown in (Table 4). Germination index of komatsuna *(Brassica rapa* var. *Perviridis*) and radish *(Raphanus sativus)* which ranged from 92.2% was recorded for radish in pile. 2, to 131.5% was recorded for komatsuna in pile. 2. Similar results by (Mitelut and Popa, 2011) obtained over 80% of germination index in radish seeds. The difference germination index among the plant species might be caused seed susceptibility also indicated presence of adequate amounts of nutrients in composts. A GI more than 80% shows free toxic and compost mature (Wang *et al*., 2004; Dadi *et al*., 2012), while below 50% indicated immature compost which might can inhibit to plant growth.

Conclusion

This study was confirmed that added feedstock is that they contributed the reduction C/N ratio and enhanced quality of coffee husk. In general, the co-composting of coffee husk has met quality compost standard. Compost pile. 2 showed the greatest reduction in C/N ratio and highest germination index (GI) for Komatsuna *(Brassica rapa* var. *Perviridis)* (14.21 ± 0.2 and 131.5%, respectively).

Acknowledgement

The author (E.H) would like to thanks to the (MEXT scholarship) Ministry of Education, Culture, Sports, Science, and Technology for funding while studying Master Degree in Prefectural University of Hiroshima.

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Chapter - 2

Effect of Improved Fallows of Some Leguminous Shrubs on soil N-Mineralization in Maize Production in Semi-Arid Areas of Tanzania

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Chapter - 2

Effect of Improved Fallows of Some Leguminous Shrubs on soil N-Mineralization in Maize Production in Semi-Arid Areas of Tanzania

E.E. Chingonikaya

Abstract

A study to evaluate the effect of various improved fallows on soil N mineralization was carried out at Gairo, a semi-arid area, in Morogoro, Tanzania. A complete randomised block design with three replications was used. Fallow types (*Cajanus cajan* (L) Mill sp., *Gliricidia sepium* (Jac Q.) Walp, *Sesbania macrantha* Phil.& Hutch, *S. sesban* (L) Merril and natural fallow) formed the treatments in replicates. At the beginning and at the end of the fallow period, soil samples were collected for determination of pH, electrical conductivity, organic carbon, total and mineral nitrogen for site characterisation and determination of effects of improved fallows on soil nitrogen mineralisation. *Gliricidia sepium* fallow led to highest nitrogen soil mineralisation, while natural fallow had the least nitrogen mineralisation. Improved fallow of nitrogen fixing species in semi-arid areas are therefore, promising to reduce problems of soil fertility depletion through recovering soil N to be available for crop production, especially maize.

Keywords: soil N-mineralisation, fallow, gliricidia, sesbania, cajanus, ammonium, nitrate

1. Introduction

Soil nitrogen mineralisation in crop production is an essential mechanism for improving productivity in both tropical and temperate areas [1]. The major constraint to agricultural production in semi-arid areas of tropical Africa including Tanzania is the inherent low nitrogen (N) [2, 3]. provide explanation on how nitrogen is important to nutrition of crops, which its deficiencies limit growth and productivity per plant and land unit area. In semi-arid areas, nitrogen deficient has been becoming a great threat to smallholder crop farming households [4, 5] especially in maize production. Many efforts have been done to solve problems related with low productivity caused by N deficiencies [6]. Among these efforts include crop intercropping with leguminous plants, which are highly fixing nitrogen [7] and expansion of more land [8]. However, these have not been effective in recent time agronomic perspective and declining of land following increased population demands for crop production. Climate change is also observed to reduce arable land through increased frequent droughts [9]. Application of inorganic fertilisers has been an immediate solution, but it is costly to smallholder farmers to afford following unavailability and high prices of the fertilisers, especially in semi-arid areas of Africa including Tanzania [10]. Further, the frequent use of inorganic fertilisers is not environment friendly and sometimes causes natural fertility depletion [10]. The use of organic fertilisers has also been indicated to increase soil fertility and hence crop productivity [11, 12]. However, the use of organic fertilisers is not effective due to labour intensity and costly if it has to be applied in large sized farm land [13].

Alternatively, improved fallows of fast-growing trees have been observed to improve soil fertility [14, 15], hence increased crop productivity. However, they have not been widely tested for semi-arid areas of Tanzania. This could be attributed to, among others, little knowledge of trees/shrubs that should be used in improved fallows, despite the fairly large number of nitrogen fixing tree/shrub species currently being used in AF systems [16, 17, 18, 19, 20, 21, 22]. Little has been known on how the fast-growing nitrogen fixing shrubs improves nitrogen. In addition, there are many shrubs, which the smallholder farmers cannot manage to handle them due to various reasons including silvicultural practices of each species, capacity of shrub species to release mineral nitrogen in the soil, labour, time and financial implications [23].

Against this background, this study was carried out to generate information on the effect of fast-growing trees/shrubs used for improved fallows on soil nitrogen mineralisation. The goal of this study, therefore, was to compare the effect of two-year-old improved fallows of *Cajanus cajan* (L) Mill sp., *Gliricidia sepium* (Jac Q.) Walp, *Sesbania macrantha* Phil. & Hutch and *Sesbania sesban* (L) Merril on soil N -mineralisation.

2. Materials and Methods

2.1 Site description

The experimental area is located at Gairo (36º 45' E, 6º 30' S; 1350 m a.s.l) in Morogoro, Tanzania. It has a slope of approximately 3-5%. There is no weather station in the immediate vicinity of Gairo. The data from Kongwa

Ranch (1961-1978) some 40 km from Gairo tends to show the general pattern [19]. Rainfall is unevenly distributed, and varies from year to year, with the rain season starting in November and ending in May. The average annual rainfall is in a range of 388-656 mm [19]. The natural vegetation was miombo woodland consisting of sparse shrubs and a few scattered trees of *Acacia*, *Brachystegia*, *Julbernardia* and *Isoberlinia* species.

2.2 Experimental design and treatments

A complete randomised block design with three replicates was used. Fallow types of *Cajanus cajan* (L) Mill sp., *Gliricidia sepium* (Jac Q.) Walp, *Sesbania macrantha* Phil.& Hutch, *S. sesban* (L) Merril. and natural fallow were the main treatments. Prior to establishment of this experiment the area was subjected to shifting cultivation and the major crops were maize and sweet potatoes. The whole area was ploughed and harrowed before planting of the shrub species. With the exception of *C. cajan*, which was directly sown, all other shrubs were grown from seedlings raised following standard nursery techniques. Plot size of 15 x 19 m was used. Distance between plots was 4 m. In each plot, an inner plot was made of 3 by 4 rows of shrubs. The spacing between shrubs was 1 m within rows and 2 m between rows. All plots with exception of the natural fallow plots were weeded twice times during the rainy season and once during the dry season. The natural fallow plots were not weeded at all. Some selected soil properties at the time of establishing the experiment are shown in Table 1.

A complete randomised block design with three replicates was used. The fallow types (natural fallow, *Gliricidia sepium*, *Sesbania sesban*, *Sesbania macrantha* and *Cajanus cajan*) were the main treatments.

Table 1: Some chemical and physical properties of soil just before establishment of the experiment at Gairo in Morogoro, Tanzania

	Soil depth (cm)				
Properties	**0-10**	**10-20**	**20-30**	**30-50**	**>50**
EC (dS m^{-1})	0.05[a] (0.01)	0.04 (0.03)	0.04 (0.01)	0.03 (0.03)	0.03 (0.01)
PH (H_2O)	6.53 (0.26)	6.68 (0.01)	6.82 (0.16)	6.85 (0.08)	6.79 (0.11)
OC (%)	1.67 (0.12)	1.65 (0.16)	1.23 (0.05)	0.72 (0.17)	0.46 (0.09)
Bray-1 P (mg kg^{-1})	3.29 (0.62)	1.85 (0.49)	1.88 (0.38)	1.34 (0.17)	0.72 (0.09)
Total P (mg kg^{-1})	245 (33.29)	263 (29.06)	275 (89.49)	225 (17.56)	248 (63.66)
Total N (%)	0.11 (0.01)	0.09 (0.01)	0.10 (0.02)	0.07 (0.01)	0.07 (0.02)
CEC (cmol(+) kg^{-1})	6.67 (0.77)	6.50 (1.09)	9.13 (1.26)	7.93 (0.55)	6.67 (0.27)

Exchangeable cations (cmol(+) kg^{-1})

Ca^{2+}	3.17 (0.07)	3.27 (0.36)	4.25 (0.68)	3.97 (0.22)	3.68 (0.19)
Mg^{2+}	1.69 (0.17)	2.21 (0.52)	2.60 (0.38)	3.05 (0.40)	3.42 (0.07)
K^{+}	0.54 (0.10)	0.52 (0.04)	0.55 (0.15)	0.28 (0.04)	0.22 (0.02)
Na^{+}	0.13 (0.01)	0.21 (0.06)	0.14 (0.01)	0.17 (0.02)	0.16 (0.01)

Physical properties

BD g cm^{-1}	1.19 (0.08)	1.28 (0.11)	1.34 (0.05)	1.37 (0.11)	1.24 (0.09)
Silt (%)	3.33 (1.76)	2.33 (0.33)	9.33 (3.53)	2.33 (0.88)	4.67 (1.33)
Clay (%)	11.33 (2.40)	16.33 (4.70)	19.33 (2.67)	29.00 (1.00)	25.33 (2.40)
Sand (%)	85.33 (1.33)	81.33 (4.37)	71.33 (1.33)	68.67 (0.67)	70.00 (3.06)
Texture	Loamy sand	Sandy clay loam	Sandy clay loam	sandy loam	sandy clay loam

[a] Mean of three replications with standard errors in parentheses.

Just before the onset of the third growing season, vegetation in all plots was cleared manually. All shrubs were harvested. Non-wood materials were incorporated into the soil during hoeing while the wood material was removed from the plots one week before sowing of maize. Maize was sown at the spacing of 0.6x0.9m. Clean weeding was done after every three weeks.

2.3 Data collection

2.3.1 Soil sampling

Soil samples were taken in two phases: for routine analysis and for determination of potentially available N. For site characterization, soil samples were taken at the time of experimental establishment. For each block, five randomly selected points were located, soil pits dug to over 50 cm depth, soil samples taken at 0-10cm, 10-20cm, 20-30cm, 30-50cm and > 50 cm, bulked by soil depth, thoroughly mixed and sub-sampled for future laboratory analysis. For determination of the effects of improved fallow on soil fertility, five soil samples were taken per major plot at depths of 0-15cm and 15-30 cm. For each major plot, all the soil samples were bulked by soil depth, mixed thoroughly and sub-samples taken for laboratory analysis.

Soil samples for determination of potentially available N were taken from each plot. The samples were taken from 5 randomly selected points at depths of 0-15 cm and 15-30cm. The samples were taken after every two weeks starting from the week of maize sowing up to the 12th week (i.e. 0, 2, 4, 6, 8, 10 and 12 weeks after sowing). Within each plot, soil samples were bulked by soil depth, mixed thoroughly and sub-samples taken to the laboratory. The soil sub-samples by respective soil depth were stored at temperature below 4 ^oC.

2.3.2 Laboratory procedures

Soil texture was determined by the hydrometer method as described by [24]. For determination of soil bulk density, soil samples were taken and analysed as described by [25]. Soil sub-samples were air dried and ground to pass through a 2 mm sieve. A 0.5 g of soil sample was digested and analysed as described by [25] and Ingram (1993). Total N in each digest was determined by semi-micro Kjeldahl procedure while total P and available P were determined by ascorbic acid method and by Bray-1 method, respectively [25]. Soil pH and electrical conductivity were determined potentiometrically using a glass electrode pH-EC meter using 1:2.5 soil: water ratio as described by [26]. Soil organic carbon was determined by wet oxidation and titration method [25]. Soils for determination of cation exchange capacity (CEC) were extracted by neutral ammonium acetate followed by analysis as follows: Displaced exchangeable K^+ and Na^+ were determined by flame emission spectrophotometry. The Ca^{2+} and Mg^{2+} were determined by atomic emission spectroscopy [27].

Potentially available N was determined as described by [28] as follows: For every sampling date, soil moisture content and disturbed bulk density were determined before further mineral N analysis. Soil samples were filled to brim in well labelled crucible with known weight and volume. The soil filled crucibles were oven dried (105 ^oC) to constant weight. Then moisture content and bulk density were calculated [29]. After determining the moisture and bulk density of each soil sample, the percentage of soil pore space was determined by using the following formula as adopted from [29]:

Porosity = (1 - (bulk density/2.65)) x 100.

Where: 2.65 is particle density of mineral soil (g cm^{-3}).

In each sample, fifty grams of oven dry (105 ^oC) soil were taken for aerobic incubation. Soil moisture for each sample was adjusted to 70% field capacity. It was assumed that 60% of porosity equals to field capacity [29]. Then the 70% field capacity was computed as follows: Field capacity = ((porosity) x ((weight of dry soil)/(Bd)) x (60%) x (70%)).

The plastic bottles covered with polythene paper with small pores were used for keeping the soil samples during incubation. The whole content was weighed before incubating at 26 ^oC for 14 days. Every day the incubator was opened for 5 minutes to allow aeration, meanwhile, moisture correction was made after weighing each bottle, by adding a corresponding amount of distilled water [28].

At time zero, that is beginning of the incubation, a 5 g of oven dry (105 ^{o}C) soil sub-sample was taken from each sample for determination of initial mineral nitrogen (nitrate-N and ammonium-N) content. An extraction of the soil sub-samples (5 g) was made according to [25]. Nitrate-N was determined by calorimetric procedure, while NH_4^+-N by distillation-titration procedure as for total nitrogen [25]. After incubation for 14 days, procedures of extraction and determination of NO_3-N and NH_4^+-N were done as at time zero.

2.4 Data analysis

All statistical analyses were carried out using general linear model (GLM) procedures of Statistical Analysis Systems (SAS) [30]. For pre-fallow site characterization, some soil chemical and physical properties were sorted by sampling soil depths. Means and standard errors were then calculated. For evaluation of effects of different fallows, on some soil fertility properties were sorted by soil depth and for each soil depth, analysis of variance was done on plot means to test the hypothesis that there are no differences between fallow types. Means separation was done by Duncan's Multiple Range Test (DMRT) for some chemical properties i.e., electrical conductivity, pH, organic carbon, total N, Bray - 1 available P, total P, CEC and exchangeable Na^+, K^+, Mg^{2+} and Ca^{2+}.

After laboratory procedures the data were sorted by sampling date, fallow type and soil depth. For determination of net mineral NO_3-N and NH_4^+-N in a respective fallow type, sampling date and soil depth, mineral N (i.e. NO_3-N and NH_4^+-N) at time zero (i.e. before incubation) was subtracted from mineral-N after incubation. For a given sampling date, potentially available mineral-N was obtained by summing up net ammonium-N and net nitrate-N concentrations. For ANOVA, initial mineral N concentration (NO_3-N and NH_4^+-N), net NO_3-N, net NH_4^+-N and net mineral-N (i.e. NO_3-N plus NH_4^+-N) were subjected to GLM procedure of SAS using plot means to test the hypothesis that there are no differences between fallows. Means were separated by DMRT [30].

3. Results

3.1 Field mineral N dynamics

The results for field (initial) mineral nitrogen concentrations i.e NO_3^--N and NH_4^+-N are presented in Figure 1. For NO_3^--N within 0 - 15 cm soil depth, significant differences among improved fallows were observed at all sampling dates with exception of week 4 and 12. Improved fallow of *G. sepium*, *S. sesban* and *S. macrantha* showed generally, higher levels of field NO_3^--N concentrations than *C. cajan* fallow at all sampling occasions (Figure 1a). Natural fallow resulted in least NO_3^--N during the cropping season. For 15 - 30 cm soil depth, field NO_3^--N concentration was significantly ($P < 0.05$) different between fallow types at weeks 0, 4, 8 and 12 only. Between weeks 0 and 8, improved fallow of *G. sepium* released highest NO_3^--N into the soil (Figure 1b). This was followed by *S. macrantha* and *S. sesban*, while *C. cajan* and natural fallow resulted in the least values of NO_3^--N level. Between weeks 8 and 12, improved fallows of *S. macrantha,* and *S. sesban* showed higher nitrification than other fallows.

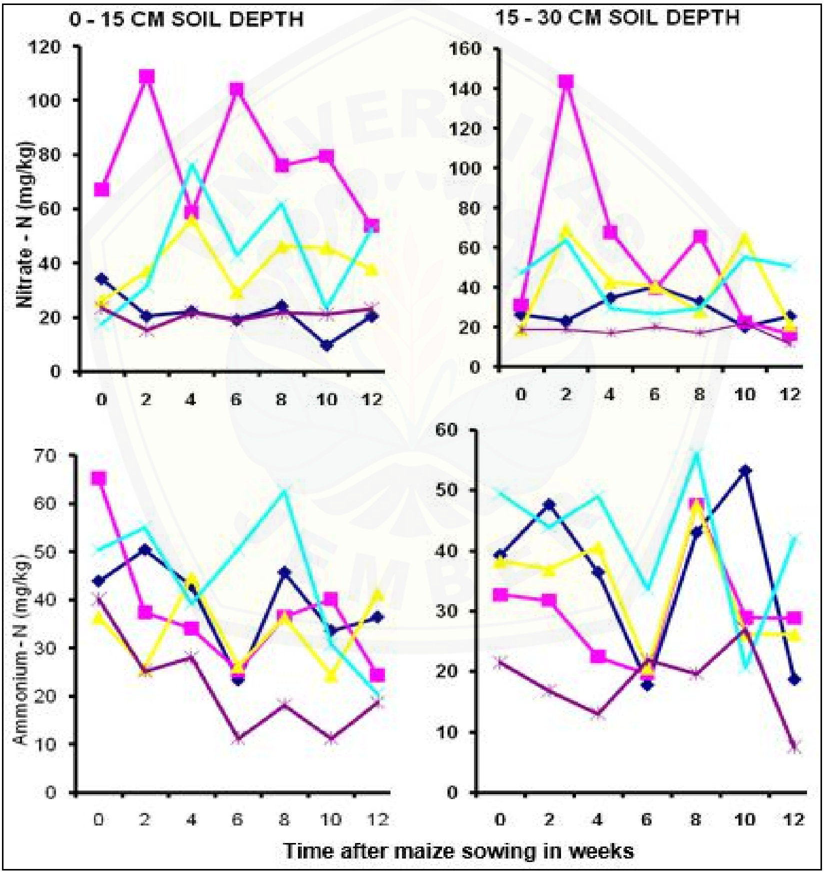

Fig 1: Effect of different fallows on field mineral N in terms of nitrate and ammonium concentrations at Gairo, Morogoro, Tanzania. (Bars are standard errors of the mean of three replicates)

For 15-30cm soil depth, significant ($P<0.05$) differences between fallows were observed in NH_4^+-N at all sampling occasions with exception of the 6th sampling occasion (Figure 1d). Improved fallows of *S. sesban* resulted in the highest NH_4^+-N concentration during the first 8 weeks. This was followed by *C. cajan* and *S. macrantha*. However, a rapid decline in NH_4^+-N was observed during the 6th week. Thereafter NH_4^+-N increased up to the 8th week. This was followed by a rapid decline in NH_4^+-N for all improved fallows, with exception of *C. cajan* which increased during week 10 (Figure 1d). Generally, improved fallow of *S. sesban* was found to rank highest in improving NH_4^+-N in the soil followed by *C. cajan* and *S. macrantha* as compared to *G. sepium* and natural fallows.

3.2 Nitrogen mineralization

3.2.1 Nitrate-N

For mineralized N in terms of NO_3^--N, the results are shown in Figure 2. Within 0 - 15 cm soil depth, there were no significant ($P > 0.05$) differences in NO_3^--N concentration among fallows at 0, 6 and 8 weeks after sowing of maize. However, significant differences were observed among fallows on other sampling occasions. During the week of sowing of maize, improved fallow of *G. sepium* had the highest nitrate (71.65 mg N kg^{-1}) concentration, followed by *S. sesban* (53.13 mg N kg^{-1}) and *S. macrantha* (45.87 mg N kg^{-1}). In general potentially available nitrate for all fallows increased between 2 and 6 weeks, whereby *G. sepium* fallow released between 79.87 and 154.67 mg N kg^{-1}, *C. cajan* 56.43-225.17 mg N kg^{-1}, *S. sesban* 53.13-70.80 mg N kg^{-1} *S. macrantha* 36.56-113.47 mg N kg^{-1} and natural fallow 26.03-155.20 mg N kg^{-1}. Thereafter, there was low nitrification within fallows. Moreover, improved fallows of *S. macrantha*, *S. sesban*, *C. cajan* and natural fallow did not show significant differences (Figure 2a).

Within 15-30 cm soil depth, there was significant ($P < 0.05$) difference among fallow types on all sampling dates, with exception of 0 and 2 weeks. During week 0, plots of *S. sesban* had highest values of mineralized nitrate (81.50 mg N kg^{-1}), followed by *G. sepium* (53.93 mg N kg^{-1}) and *C. cajan*, (44.55 mg N kg^{-1}), while the natural fallow showed the least value (27.87 mg N kg^{-1}). Similar results were obtained during the second sampling date (week 2), but during this period mineralized nitrate ranged between 24.47 mg N kg^{-1} (natural fallow) and 169.33 mg N kg^{-1} (*S. sesban* fallow). Generally, *G. sepium*, *S. sesban* and *S. macrantha* fallows resulted in highest nitrification especially during the first 6 weeks (Figure 2b).

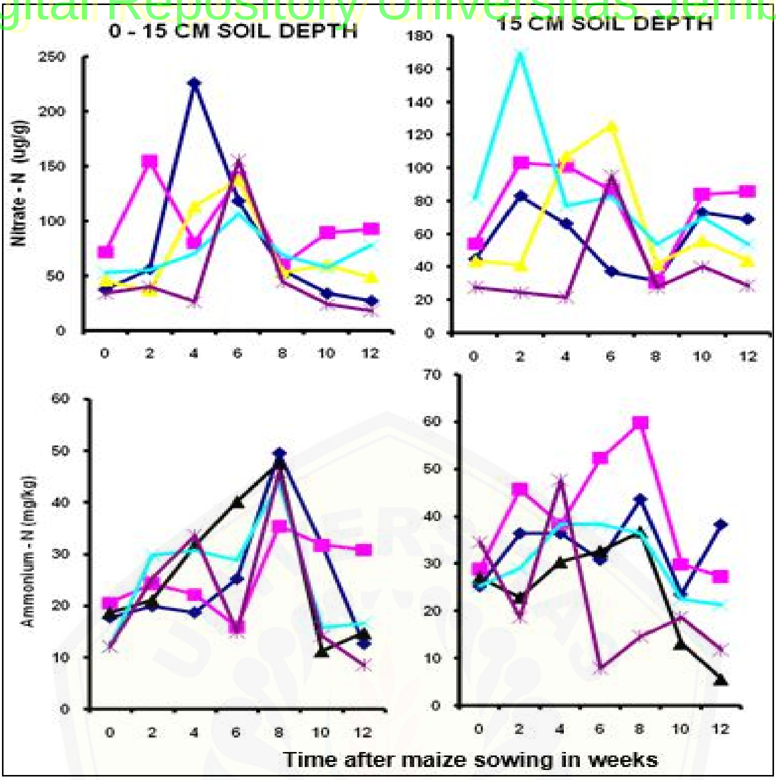

Fig 2: Effect of different fallows on mineralizable nitrogen changes in terms of nitrate and ammonium at Gairo, Morogoro, Tanzania (Bars are as defined in Figure 1)

3.2.3 Ammonium-N

Within 0-15 cm soil depth, there were no significant ($P > 0.05$) differences in ammonification between improved fallow types. At 0 week after sowing of maize, NH_4^+-N ranged between 12.13 mg N kg^{-1} for natural fallow and 20.53 mg N kg^{-1} for *G. sepium*, while at week 2 it ranged from 19.80 mg N kg^{-1} (*C. cajan*) to 29.86 mg N kg^{-1} (*S. sesban*), at the 4th week, 18.67 mg N kg^{-1} for *C. cajan* and 33.60 mg N kg^{-1} for natural fallow. Higher rates of ammonification occurred during week 8 when NH_4^+-N ranged from 35.47 mg N kg^{-1} (*G. sepium* fallow) and 76.6 mg N kg^{-1} (*C. cajan* fallow), but thereafter, there was a general decline in ammonification (Figure 2c).

Within 15-30cm soil depth, mineralized NH_4^+-N was significantly ($P < 0.05$) different among fallow types only during weeks 6 and 12. During week 0, natural fallow had higher values of NH_4+-N (34.53 mg N kg^{-1}) while *C. cajan* and *S. sesban* had least NH_4^+-N concentration of 25.20 $mgNkg^{-1}$. During week

6, *G. sepium* fallow resulted in high ammonification, while natural fallow exhibited least ammonification. During the 12th week, NH_4^+-N concentration was highest in soils from *C. cajan* fallow. This was followed by *G. sepium* and *S. sesban* fallows, but natural fallow and *S. macrantha* exhibited least NH_4^+-N concentration (Figure 2d). Despite the fact that all types of fallows did not show great variation in mineralized NH_4^+ - N, natural fallow was inferior as compared to other improved fallows (Figure 2d,).

3.2.4 Net potentially available nitrogen

The results for net potentially available N (NO_3^- - N plus NH_4^+ - N) concentration are presented in Figure 3. Within the 0 - 15 cm soil depth, net potentially available nitrogen was significantly ($P < 0.05$) different during weeks 2, 4, 10 and 12 weeks after sowing of maize. Higher net N mineralization was observed in *G. sepium, C. cajan* and *S. macrantha* fallows. Net N mineralization increased up to week 6 for all types of fallow, with exception of *G sepium* fallow which fluctuated after every 2 weeks (Figure 3a). Thereafter, there was a decrease in net nitrogen mineralization up to the 12th week, although *G. sepium* and *S. sesban* fallows resulted in a gradual increase in net mineralization (Figure 3a).

For 15-30cm soil depth, no significant differences ($P > 0.05$) in net potentially available nitrogen among fallow types were observed on all sampling dates with exception of sampling at week 2 after maize sowing. During this week, *S. sesban* fallow had the highest values of net potentially available N (198.2 mg N kg^{-1}) followed by *G. sepium* (148.8 mg N kg^{-1}) and *C. cajan* (119.33 mg N kg^{-1}). The least values were found in *S. macrantha* (63.93 mg N kg^{-1}) and natural fallow (43.13 mg N kg^{-1}). This trend continued up to week 6. This was followed by a gradual decline in net available N (Figure 3b). The overall performance of improved fallow types on soil nitrogen availability can be ranked as *G. sepium* > *S. sesban* > *S. macrantha* > *C. cajan* > natural fallow.

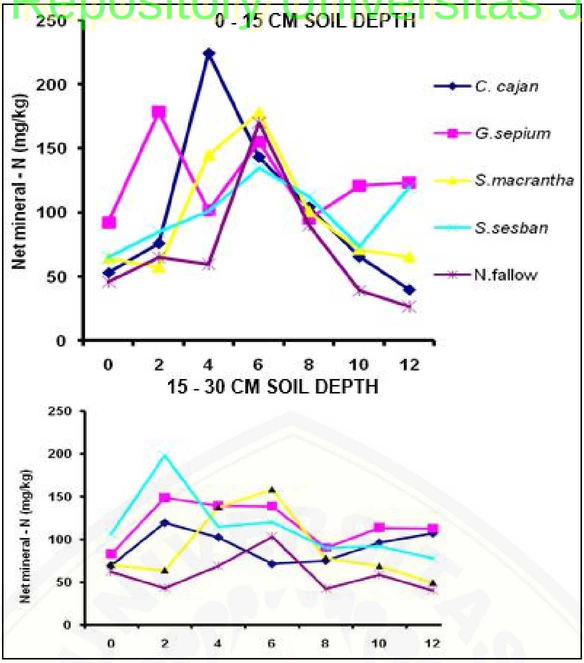

Fig 3: Effect of different fallows on net potentially available nitrogen (NO_3-N plus NH_4^+-N) at Gairo, Morogoro, Tanzania. (Note: *G. sepium* prunings were added after every three weeks). (Bars are as defined in Figure 1)

4. Discussion

The results for mineral nitrogen changes are shown in figures 1, 2, 3. During the whole period of the growing season, nitrate-N was the dominant form of the total extractable mineral N (NO_3^--N plus NH_4^+-N). This indicates that the system is highly nitrifying. These findings are in agreement with those of) and [31, 28] but in sharp contrast with those of), [32, 33, 34] who observed that more than 70% of the system was dominated by ammonification activity. However, they worked on acidic soils. The possible explanation is that soils in Gairo have near neutral pH which favours nitrification processes. Also higher NO_3^--N than NH_4^+-N concentrations in the soil is partly explained by high immobilization of NH_4^+-N through either microbial assimilation [35, 36] or oxidation of NH_4^+-N into NO_3^--N [37]. These results confirm earlier findings that nitrate ions are the dominant form of mineral N which are readily available and easily removed from the agricultural soil as compared with ammonium ions [38].

It has been found in the present study that fallows of *G. sepium* and *S. sesban* resulted in highest field mineral N and nitrogen mineralization during the whole period of growing season. This is due to the fact that these are fast growing species with high nutrient demand and much more efficient in taking up sub soil nitrate [39, 40] found that a two-year old improved fallow of *S. sesban* removed high amounts of nitrates from subsoil horizon to surface soil. Also high nitrogen availability in soils from fallows of *G. sepium* and *S. sesban* may be associated with the lower C/N ratios of their tissue materials [41, 42, 43, 32, 44] and already existing nitrogen in the soil during fallow period thus creating favourable conditions for mineralization and nitrification.

Despite the differences exhibited by fallow types, in the first 6 weeks, all improved fallows, i.e. *G. sepium*, *S. sesban*, *C. cajan* and *S. macrantha*, showed high rates of N mineralization compared to natural fallow. This may be attributed to enough mineralizable material during that period. For example, [28] indicated that leguminous shrubs, especially, *S. sesban* and *G. sepium* had highest decomposition rates between the 4th and 10th weeks.

High levels of nitrogen mineralization in this study are in complete agreement with [33] who observed that fresh earthworm casts of *Pontoscolex corethrurus* resulted in net nitrogen mineralization of 160 mg N kg^{-1} [28]. Observed that net potentially available N from relay intercropping of *S. sesban* and maize was between 13.67 and 144.90 mg N kg^{-1}. However, these values are considered higher as compared to those of [45] who worked on improved fallows of *P. chilensis*. On the other hand the values are lower than those reported by [31] who worked on *G. sepium* mulch mixed with soils and sawdust. The values of this study are also lower than those reported by [46] who showed that materials of soy beans and Egyptian clover resulted in net N ranging between 50 and 500 mg N kg^{-1}.

5. Conclusions and Recommendations

These field mineral N concentrations and mineralization values show that fallows of leguminous shrubs in semi-arid areas of Gairo, Morogoro are suitable for improving inorganic N in the soil. Nitrogen availability potential following two-year old improved fallows of leguminous shrubs is seemed adequate for maize productivity. Nitrate level in the soil was dominant compared to ammonium level. This is due to neutral soil pH. High level of nitrate indicates that the soil mineral N at Gairo is unstable and there is a high rate of nitrification. All improved fallows of *G. sepium, S. sesban, S. macrantha* and *C. cajan*, resulted in highest mineral N and net N mineralization compared to the natural fallow. According to the findings obtained in this study, *G. sepium* and *S. sesban* fallows should be tested on farm. However, other species such as, *S. macrantha* and *C. cajan* can also be tested on farm.

Acknowledgements

I thank the Norwegian Agency for Development Cooperation (NORAD) for funding this study through the Sokoine University of Agriculture/NORAD Frame Agreement. I thank N. Swalehe, S. Mnyonga and M. Mackihiyo for assistance with field work and Mrs. E. Mtengeti for assistance with laboratory work.

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Chapter - 3

Heavy Metals-Their Sources, Behaviour and Effect on Nutrient Availability and Remediation Measures

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Chapter - 3

Heavy Metals-their Sources, Behaviour and Effect on Nutrient Availability and Remediation Measures

G.K. Surya Krishna, V. Sai Surya Gowthami, CH. Sujani Rao and M. Latha

Abstract

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition. Heavy metals constitute an ill-defined group of inorganic chemical hazards and those most commonly found at contaminated sites are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg) and nickel (Ni). Their toxicity depends on several factors including the dose, route of exposure and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals. Heavy metals are natural components; they cannot be destroyed or degraded. The substantial concentration of heavy metals in textile effluent is a worldwide environmental problem. These effluents are directly discharged into the surface water, ultimately contaminating both surface and ground water by leaching. Being persistent pollutants, heavy metals accumulate in the environment and consequently contaminate the food chains. Accumulation of potentially toxic heavy metals in biota causes a potential health threat to their consumers including humans.

Keywords: contaminated, toxicity, heavy metals, persistent pollutants

Introduction

Heavy metals (HMs) are considered crucial toxicants of the environment as they are very toxic, tenacious, easy to accumulate, and nondegradable in nature. Heavy metals exert toxic effects on soil microorganism hence results in the change of the diversity, population size and overall activity of the soil microbial communities. Prolonged exposure and higher accumulation of such heavy metals can have deleterious health effects on human life, soil, air and aquatic biota. The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants. The metal plant uptake from soils at high concentrations may result in a great health risk considering food-chain implications. The consumption of heavy metal contaminated food can seriously deplete some essential nutrients in the body that are further responsible for decreasing immunological defences, intrauterine growth retardation, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates. Heavy metals containing agricultural runoff enter in aquatic environment it may toxic to aquatic plants and animals.

What is a heavy metal?

- The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations.
- Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Ti) and lead (Pb).
- Heavy metals are those having densities five times greater than water and the light metals are those having lesser densities.
- Humans consume metallic elements through both water and food.

Distribution of heavy metals in environment

Natural sources

Heavy metals in rocks

- Rocks are one of the natural sources for heavy metals in the environment. Rocks are classified into magmatic rocks, sedimentary rocks and metamorphic rocks.
- The most common heavy metals occur in rock are Ni, Co, Mn, Li, Zn, Cu, Mo, Se, V, Rb, Ba, Pb, Ga, Sr, F, etc.

Heavy metals in soils

- Generally, the minerals are dissolved by interacting with carbonic acid and water.
- The insoluble minerals are dispersed into fine particles. Soils are contaminated by metals and metalloids from metal wastes, gasoline, animal manure, sludge, waste water irrigation, atmospheric deposition etc.
- The most common heavy metals found in soils are Pb, Cr, Zn, Cd and Hg.

- Due to bioaccumulation and biomagnification, these metals decrease the crop production and affect the food chain.

Table 1: Major sources of soil contamination

Chemicals	Major sources of soil contamination
Arsenic	Pesticides, plant desiccants, animal feed additives, coal and petroleum, mine tailings and detergents
Cadmium	Electroplating, pigments for plastics and paints, plastic stabilizers and batteries, fertilizers
Chromium	Stainless steel, chrome-plated metals, pigments and refractory brick manufacture
Lead	Combustion of oil, gasoline and coal; iron and steel production
Mercury	Pesticides, catalysts for synthetic polymers, metallurgy, thermometers
Nickle	Combustion of coal, gasoline, oil; alloy manufacturing, electroplating, batteries

Table 2: Heavy metals prevailing in soils and their regulatory limits

Element	Concentration range (mg/kg)	Regulatory limit (mg/kg)
Lead	1-6900	600
Cadmium	0.1-345	100
Arsenic	0.1-102	20
Chromium	0.005-3950	100
Mercury	0.001-1800	270
Copper	0.03-1550	600
Zinc	0.15-5000	1500

Heavy metals in water

- Metal composition in surface water like rivers, lakes, ponds, etc. is influenced by the type of soil, rock and water flow.
- Metals present on the surface of soil are carried out from its path, which ends up in sewage and reservoirs.
- The rain water gets contaminated while passing through the atmosphere. Water sources get contaminated by the flow of various industrial effluents into it.
- Factors such as temperature, pH, living organism, cation exchange, evaporation, absorption etc., will also influence the metal composition in the water.

Heavy metals in atmosphere

- Heavy metals are released into the atmosphere as gases and particulates by surface erosion and colloid loss.

- Sources of heavy metals in the atmosphere include mineral dusts, sea salt particles, volcanic eruption, forest fires.
- Other than these natural sources, heavy metal air pollution can also originate from various industrial processes that involve the formation of dust particles, e.g., metal smelters and cement factories.
- Volatile metals such as Se, Hg and As are transmitted in gaseous and particulate form in the atmosphere.
- Metals such as Cu, Pb, and Zn are transported as particulate form.
- The presence of heavy metal depends upon number of site-specific factors such as

(1) The quantity and characteristics of the industrial pollutants.

(2) Environmental sensitivity.

(3) Potential for environmental release.

Impact of textile effluents containing heavy metals on soil properties

Colour and odour

- The colour of the textile effluent is in different colour like blue red, brown, dark brown and sometimes yellow colour also that depends on type of dye used in the textile mill.
- Dark brown colour can affect the photosynthetic activity in aquatic life and pose problem for BOD and COD.
- The odour of the effluent is unpleasant due to use of different metal substances.

pH

- pH is one of the important biotic factor that serves as index for pollution.
- The optimum pH range required for crops in the soil is from 6.5-7.5, which is considered as neutral range for crops.
- The effluent water increases pH and makes the soil alkaline and saline due to use of higher quantities of basic dyes for dyeing, and use of other alkali based chemicals during different steps of printing and dyeing.

Electrical conductivity

- The amount of soluble salts in the soil has direct relationship with the conductivity as it is the current carrying capacity of soil.
- In the contaminated soil, EC increased with the application of effluent as irrigation water having high concentration of salts, particularly Na^+ and Cl^- has significantly increased the salinity as compared to the uncontaminated soil.
- The higher concentration of cations such as Na and K in waste water led to an increase in EC and exchangeable Na and K in soil irrigated with waste water.

Soil organic matter

- Soil organic carbon (OC) and organic matter (OM) have long been identified as factors that are important for soil fertility in natural ecosystems.
- Organic carbon and Organic matter was slightly higher in contaminated soil which indicates the prolonged accumulation of carbon in soil.
- The higher OM results in the increase water content at field capacity, available water content in sandy soil and increases both air and water flow rates through fine textured soil.

Water holding capacity

- Water holding capacity shows physical condition of soil, it is the point at which soil gets completely saturated with water.
- Pollutants and industrial discharges increases the soil water holding capacity because these pollutants can increase the soil organic matter.

Ca^{2+}, Mg^{2+}, Na^+

- The amount of $Ca^{2+,}$ Mg^{2+}, Na^+, ions in impacted soil were much higher as the soil was contaminated from industrial effluents.
- This increase in concentration of $Ca^{2+,}$ Mg^{2+}, Na^+ also supports the higher pH of the soil due to effluent exposure.
- The increase amount of sodium ions in the industrial discharge results in precipitation of calcium and magnesium ions.

Nitrogen

- Increase in rate of textile effluent application, increased the alkaline $KMnO_4$-N content of the soil.
- This might be due to the addition of organic matter in the form of textile effluent would have provided the source of N for the multiplication of microbes and subsequent increase in the nutrient availability during decomposition process.
- If the long time application of textile effluent as irrigation to the agricultural lands there may built up toxicity substances in the soils of the area.

Phosphorus

- Soil irrigated with waste water contains high amount of available phosphorus which play significant role in plant growth.
- Soil available P contents were the highest in soil treated with 50% wastewater and decreased considerably at 75 to 100% wastewater application rate due to built up toxic substances surrounding the agricultural land.

Potassium

- Application of industrial waste/effluent markedly improved the soil available potassium in contaminated soil as compared to uncontaminated soils.
- The available K in the soil got increased 4 to 5 times due to the textile effluent irrigation which might be due to the fact that K was one of the components supplied in larger quantities.

Effects of potentially toxic elements on soil, plants and human health

Toxic Elements	Soil	Plants	Human Health
Cadmium	The application of agricultural inputs or the deposition of atmospheric contaminants increases the total concentration of Cd in soils. Cadmium in the soil also adversely affects microbial activity involved in nutrient cycling and maintenance of soil fertility.	Cadmium has a tendency to concentrate in the leafy vegetable tissues rather than in fruits and grains/seeds. Although incidence of Itai-Itai disease in the Jintsu valley of Japan occurred because of the high Cd-content of	Cadmium in the body is known to affect several enzymes. It is believed that the renal damage that results in proteinuria is the result of Cd adversely affecting enzymes

		rice, reducing soil conditions hinder the uptake of Cd by rice.	responsible for reabsorption of proteins in kidney tubules.
Lead	Pb decreases the activities of urease, catalase, invertase and acid phosphatase significantly.	Higher concentrations are more likely to be found in leafy vegetables (e.g., lettuce) and on the surface of root crops (e.g., carrots). Lead toxicity causes inhibition of ATP production, lipid peroxidation and DNA damage by over production of ROS. In addition, lead strongly inhibits seed germination, root elongation, seedling development, plant growth, transpiration, chlorophyll production, and water and protein content.	The most serious source of exposure to soil lead is through direct ingestion (eating) of contaminated soil or dust. Pb accumulates in the body organs (i.e., brain), which may lead to poisoning (plumbism) or even death. The gastrointestinal tract, kidneys and central nervous system are also affected by the presence of lead. Children exposed to lead are at risk for impaired development, lower IQ, shortened attention span, hyperactivity and mental deterioration.
Mercury	The availability of soil mercury to plants is low, and there is a tendency for mercury to accumulate in roots, indicating that the roots serve as a barrier to mercury uptake. Mercury concentration in aboveground parts of plants appears to depend largely on foliar uptake of Hg0 volatilized from the soil. In gold mining regions, the risk of soil pollution by mercury is a major environmental hazard, especially in tropical areas where soil microflora plays a major part in soil functioning,	In the uncontaminated environment, Hg-content of plant tissues seldom exceeds 500 parts per billion (ppb). In naturally contaminated areas (near Hg-bearing deposits), its level can be as high as 3500 ppb.	Mercury is associated with Severe brain damage, Loss of hearing and muscle coordination, Dysfunctions of the central nervous system, Minamata disease, Damage to vision, Damage to the kidneys, Excessive perspiration, Rashes, Irritation of nose and skin, kin burns.

	major bio-geochemical cycles and carbon turn-over.		
Nickle	Ni is extracted from ore Nickel pollution may affect microbial development and its activity in soil and, therefore, its fertility, while organic amendment may affect Ni mobility and bioavailability.	Nickel content in the range of 50 to 100 mg/g (dry weight basis) is indicative of its toxicity in plants.	Nickel contact can cause a variety of side effects on human health, such as allergy, cardiovascular and kidney diseases, lung fibrosis, lung and nasal cancer.
Chromium	The trivalent Cr is apparently useful or harmless to living organisms at reasonable concentrations, while Cr (VI) is extremely toxic. In addition, Cr (III) is not mobile in soil, therefore risks of its leaching are negligible.	Chromium is essential to human and animal life but non-essential for the vegetable kingdom.	Chromium is associated with allergic dermatitis in humans
Selenium	Selenium concentration in soil is determined by selenium content in soil native substrate, climate, relief and age. These factors may contribute either to selenium accumulation during soil forming or its removal during or after soil forming. The soils formed on sedimentary rocks that contain high amounts of organic matter typically have high to toxic selenium concentrations. The soils formed on magmatic rocks, which are poor in Se, usually have a low Se content.	Selenium is essential for animals and humans, but not for plants. Plants suffering from selenium toxicity may be stunted and may die earlier than usual. Leaves of affected plants may exhibit chlorosis or may dry and wither.	An overdose of selenium may cause bad breath, fever and nausea, as well as liver, kidney and heart problems and other symptoms. At high enough levels, selenium could cause death.
Arsenic	Arsenic builds up in the soil environment through natural processes of weathering of arsenic-bearing rocks or use of arsenic-contaminated groundwater for irrigation or through a host of anthropogenic activities such as mining operations, smelling of base metal ores, combustion of coal and application of arsenical	Arsenic is non-essential and toxic for plants, especially in higher concentrations. Roots are usually the first tissue to be cell expansion or biomass accumulation. Arsenic can reduce plants reproductive capacity through losses in fertility, reducing	Arsenic is associated with skin damage, increased risk of cancer and problems with circulatory system

	pesticides.	development of reproductive organs.	

Traditional remediation of contaminated soil

Traditional treatments for metal contamination in soils are expensive and cost prohibitive when large areas of soils are contaminated. Some treatments that are available include:

1) High temperature treatments
2) Solidifying agents
3) Washing process

Management of contaminated soil

The following management practices will not only remove the heavy metal contaminants, but will help to immobilize them in the soil and reduce the potential for adverse effects from the metal.

1) Increasing the soil pH to 6.5 or higher.
2) Draining wet soils.
3) Applying phosphate.
4) Carefully selecting plants for use on metal-contaminated soils.

Plants for environmental clean up

- Phytoremediation is a general term for using plants to remove degrade or contain soil pollutants such as heavy metals, pesticides, solvents, crude oil, polyaromatic hydrocarbons and landfill leachates
- Ex: Prairie grasses, Wild flowers.

Heavy metal removal processes from soil

1) Techniques or processes involved in soil remediation

i) Immobilization Techniques
ii) Soil Washing
iii) Phytoremediation
iv) Electro remediation

2) Heavy metal wastewater treatment techniques

i) Chemical precipitation
ii) Ion exchange

iii) Adsorption

iv) Membrane filtration

v) Coagulation and flocculation

vi) Flotation

vii) Electrochemical treatment

Technologies based on the used processes

Biological technologies

Some remediation technologies have been developed to treat contaminated soil, but a biology-based technology-“Phytoreclamation” which uses plants and their associated rhizospheric microorganisms to remove, degrade or immobilize various contaminants from polluted soils and also from sediments, groundwater or surface water has been evolved by researchers. Early research indicates that phytoreclamation is a promising clean-up solution for a wide variety of contaminated sites, although it has its limitations. It includes phytovolatilization (for effluent), phytostabilization, phytoextraction and artificial constructed wetlands using hyperaccumulator species or a chelate-enhancement strategy. To enhance phytoreclamation as a viable strategy, microbiota from the rhizosphere can play an important role.

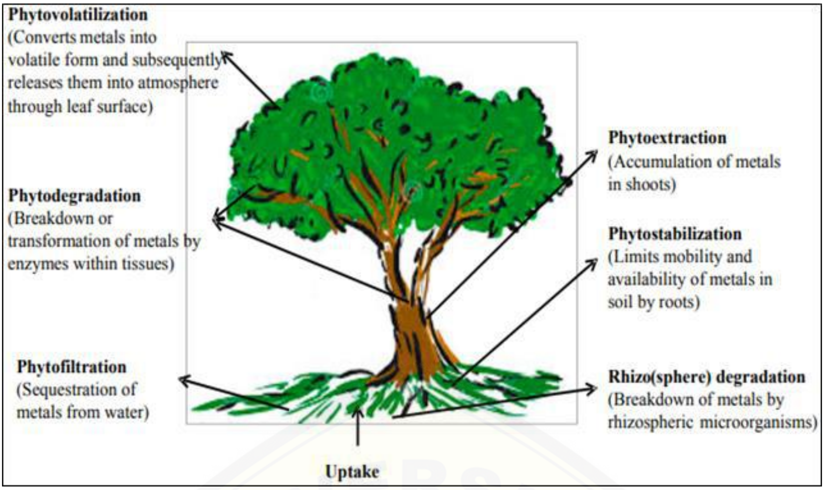
Different approaches of phytoreclamation

It can be used for both organic and inorganic pollutes of solid or liquid. Various phytoremediation strategies are possible for the remediation of contaminated soils. Different phytotechnologies make use of different plant properties.

Phytoremediation

Phytoremediation also called green remediation, botanoremediation, agroremediation or vegetative remediation can be defined as an in situ remediation strategy that uses vegetation and associated microbiota, soil amendments and agronomic techniques to remove, contain, or render environmental contaminants harmless. Potentially useful phytoremediation technologies for remediation of heavy metal- contaminated soils include phytoextraction (phytoaccumulation), phytostabilization, phytofiltration and Phytodegradation.

Various processes involved in the phytoremediation of heavy metals



Different approaches of phytoreclamation

1) Phytoextraction
2) Phytodegradation
3) Rhizofiltration
4) Phytostabilization
5) Phytovolatilization

1. Phytoextraction

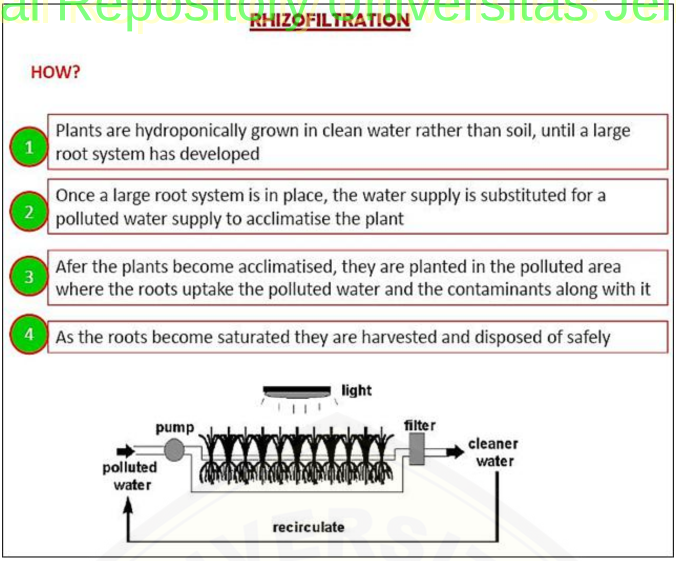
The term "phytoextraction" mainly concerns the removal of heavy metals from soil by means of plant uptake. This technology is based on the capacity of the roots of plants to absorb, translocate and concentrate toxic metals from soil to the aboveground harvestable plant tissues.

2. Phytodegradation

The use of plants and associated microorganisms to degrade organic pollutants to less toxic forms or rendering them immobilized to prevent their entry in to the food chain or environment.

3. Rhizofiltration

It is defined as the use of plants to absorb, concentrate and precipitate contaminants from the polluted aqueous sources. It can partially treat industrial discharge, agricultural runoff or acid mine drainage.



RHIZOFILTRATION

HOW?

1. Plants are hydroponically grown in clean water rather than soil, until a large root system has developed
2. Once a large root system is in place, the water supply is substituted for a polluted water supply to acclimatise the plant
3. Afer the plants become acclimatised, they are planted in the polluted area where the roots uptake the polluted water and the contaminants along with it
4. As the roots become saturated they are harvested and disposed of safely

4. Phytostabilization

The use of plants to reduce the bio availability of pollutants in the environment through reduction of leaching, run off and soil erosion. Prevent migration to the ground water or air.

5. Phytovolatilization

The chemical conversion of toxic elements into less toxic and volatile compounds is a possible strategy for detoxification of metal ion contaminants, resulting in the removal of specific harmful volatile elements (Hg and Se) from soil and plant foliage to the atmosphere. For example, the volatilization of Se involves the assimilation of inorganic Se into the organic selenoaminoacids selenocysteine and selenomethionine. The latter can be biomethylated to form dimethyl selenide, which is volatile and can be lost to the atmosphere.

Advantages of phytoreclamation

- Cost effective when compared to other conventional methods.
- "Nature" method, more aesthetically pleasing.
- Minimal land disturbance.
- Reduces potential for transport of contaminants by wind, reduces soil erosion.
- Multiple contaminants can be removed with the same plant.

Disadvantages of phytoreclamation

- Slow rate and difficult to achieve acceptable levels of decontamination
- Potential phase transfer of contaminant
- Possibility of contaminated plants entering the food chain
- Contaminant might kill the plant
- Possible spread of contaminant through falling leaves

Hyper accumulators used for reclamation

Elements	Plant species	Maximum conc. (mg/kg)
Cadmium	*Thlaspi caerulescens*	500
Chromium	*Brassica juncea, Helianthus annuus*	1400
Nickel	*Alyssum lesbiacum, Sebertia accumulate*	47000
Lead	*Thlaspi rotundifolium, Brassica juncea, Zea mays*	8200
Cobalt	*Haumaniastrum robertii*	10000
Zinc	*Thlaspi caerulescens, Brassica juncea, B. oleracea, B. campestris*	51000
Selenium	*Brassica juncea, B. napus*	900
Copper	*Ipomoea alpine*	12000

Physical separation

Physical separation treatment involves phase transfer of metal contaminants from the contaminated media by exploiting differences in certain physical characteristics between metal bearing and soil particles considering their size, density, magnetism and hydrophobic surface properties. Basically physical separation is concentration technique of metal bearing particles applied in mining and mineral processing industry but in soil remediation it indicates separation of metal particles from soil. The use of physical separation technologies is exactly depended on sorption capacity of heavy metal chemical forms in soil, their concentration level and soil properties. Thereby these technologies are mostly applied in anthropogenic influenced industrial areas with high heavy metal concentrations in anthropogenic soils.

Chemical processes

Chemical processes include reduction of the bioavailability/mobility of heavy metals as well as other contaminants upon chemical reactions with specific reagents. Technologies for heavy metal remediation are based on precipitation, oxidation-reduction and organic-metal complexation reactions that are well known and widely studied technique in chemistry, for example, chemical technology, environmental, analytical and radioanalytical chemistry. The use of chemical processes has a drawback conjugated with the possible side effects on the environment that has to take into consideration in the choice of the chemical reagents in treatment process. Dissolved heavy metals in groundwater can be precipitated out of solution in various insoluble compounds. The most common heavy metal precipitates are hydroxides, sulphides, carbonates, phosphates, oxalates and some others.

Conclusion

- Heavy metals uptake by plants from the soil reduces the crop productivity by inhibiting physiological metabolism.
- Heavy metals uptake by plants and successive accumulation in human tissues and biomagnifications through the food chain causes both human health and environment concerns.
- Implementation of biotechnological approaches is gaining increasing prominence in the field of remediation, as they are often considered as a promising strategy for the eventual treatment of contaminated sediments.
- From the study, it is quite obvious that the anthropogenic activities have been significantly contributing to high concentrations of heavy metal discharge into the environment.
- Therefore, a serious and strict monitoring of these activities is suggested as an effective solution to address heavy metal pollution.

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Chapter - 4

Humic Substances as Remediation Agents in Pollution Control

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Chapter - 4

Humic Substances as Remediation Agents in Pollution Control

Shilpa, Charan Singh, Vindhya Bundela and Sudarshan Varma

Abstract

Highly transformed part of non-organic matter (NOM) is defined as humic substances (HS) which are high molecular weight natural occurring organic substances having various functional groups. HS constitute up to 35-70% of the soil organic matter (SOM). They are brown to dark and yellow-colored organic mixtures that are usually classified into three fractions on the basis of their aqueous solubility,

a) Fulvic acids (FAs) which are soluble in water under all pH values.

b) Humic acids (HAs) which are found insoluble in acidic conditions ($pH < 2$) but they are soluble at higher pH values.

c) Humin which is insoluble in water at all pH value.

HS play vital role in numerous environment and terrestrial processes. HS act as bio stimulants in horticulture because they promote seed germination and root & shoot growth. Soil organic matter plays a key role in controlling heavy metal behavior and their pollution in soils. Heavy metals which bound on insoluble humic substances are relatively immobile. HS have positive impact on microorganisms which include detoxification resulting from their binding properties and formation of less bioavailable compounds and ultimately, bioaccumulation of metals and/organic compounds. It is supposed that formation of HS-metal complexes and metal cations adsorption on the surface of HS and soil would help in lowering the toxicity of heavy metals by reducing their free cations concentration in water. Thus, HS mitigate the inhibitory effects of heavy metals and stimulating bacterial growth. Hence in this book chapter we have discussed the role of HS in pollution control.

Keywords: bioaccumulation, humic substances, SOM and soil pollution

Introduction

Humic substances (HS) are a general category of naturally synthesized, biogenic, heterogeneous organic substances that can be characterized by yellow to black colour and are of high molecular weight possessing refractory properties. HS are very stable against the microbial degradation, and also can bind with mineral components in soil and water. HS contain functional groups capable of interacting with metal ions to form complexes with them. The protectory function of HS is the ability to link different types of pollutants. HS can also act as a "geochemical barrier" and contains functional groups such as hydroxyl, carboxyl, phenoxy and amino hydroxyl groups. HS can significantly reduce the acute toxicity of metals and bioavailability of metals. It has been proved that HS are able to bind with metal ions and change their speciation forms in soils (Burlakovs *et al.*, 2013). The ability to form complexes with metal ions depends on the type of soils, metal as well as concentrations of humic substances in soil.

Soil pollution is defined as the contamination of soil in a particular region. Soil pollution is a result of penetration of harmful pesticides and insecticides that deteriorate the soil quality making it unfit for later use. Soil contamination is caused by xenobiotic components or alteration of natural environment. This is usually caused by industrial activity, agricultural chemicals and improper disposal of waste. Rapid urbanization and industrialization led to problem of disposal of industrial wastes and their effluents (Alloway, 1990).

Sources of soil pollution

There are several factors that are mainly responsible for soil pollution, few of them may be described as follows:

Agricultural practices

Though high analytical fertilizers can increase crop yield several folds but in turn they cause pollution that impacts soil quality. Many fertilizers like phosphatic fertilizers are known to contain heavy metals in form of impurities like cadmium (Cd) and arsenic (As) which on repetitive application of fertilizers, accumulates in soils. Pesticides also harm plants and animals by contaminating the soil. These chemicals get deep inside the soil and poison the ground water system. Runoff of these chemicals by rain and irrigation also contaminate the local water system and is deposited at other locations.

Recently it has been reported by Anna university Tamil Nadu that Cauvery river water is more contaminated than Ganga river water with noticeable total dissolved salts (TDS) (756 mg L^{-1}) and use of such water for irrigation purpose causes soil pollution.

Table 1: Contribution of different components to soil pollution

Category	Subgroup	Codes	Percent
Types of Environmental Pollution	Soil Pollution	Factories	7
		Solid waste	57
		Agricultural activities	10
		Deforestation	7
		Erosion, floods	7
		Acid rain	7
		Detergents	5

Effects of agricultural practices

i) Soils that have been spoiled due to excessive use of chemicals and pesticides become barren.

ii) When plant macronutrients like potassium, phosphorus and nitrogen are used excessively, the soil becomes deficient in micronutrients like boron and zinc.

iii) Excess chemicals from agricultural practices harm the survival of a number of friendly microorganisms.

iv) Pesticides that contaminate the soil seep lower down the soil layer and contaminate groundwater that is used for domestic purposes.

Industrial Waste

Industrial waste is being produced by industrial activity and includes materials that are rendered useless during a manufacturing process such as that of factories, mills, and mining operations. About 90% of oil pollution is caused by industrial waste products. Improper disposal of waste contaminates the soil with harmful chemicals. These pollutants affect plant and animal species and local water supplies including drinking water. Toxic fumes from the regulated landfills contain chemicals that can fall back to the earth in the form of acid rain and can damage the soil profile.

The best example for this can be compared to increased chromium content in ground water samples of cities like Yelahanka and it can be attributed to industrial waste disposals with higher chromium content into nearby water bodies like lakes and their seep to the ground waters.

Effects of industrial waste

i) They spoil the fertility of the soil.

ii) The chemicals released are harmful to living organisms, dependent on the soil.

- iii) Contamination of the soil is a direct cause of contamination of the crops. As a result, harmful chemicals enter the food chain.

Urban activities

Improper drainage and increase run-off contaminate the nearby land areas or streams. Improper disposal of trash breaks down into the soil and it deposits in a number of chemical and pollutants into the soil. These may again seep into groundwater or wash away in local water system. Excess waste deposition increases the presence of harmful bacteria in the soil. Decomposition by bacteria generates methane gas contributing to global warming and poor air quality. It also creates foul odors and can impact quality of life.

Effect of urban activities

Urban wastes dirty residential areas, resulting in the growth of insects and pathogens and they are harmful to human health.

Biological agents

Biological agents like bacteria, fungi, virus and protozoans are a major cause of soil pollution. Human and animal excreta, poor sanitary conditions, wastes from hospitals and food joints cause soil pollution because they perpetrate growth of biological agents in the soil.

Effects of biological agents

- i) They cause diseases in human beings.
- ii) They harm the development and existence of flora and fauna.
- iii) They spoil qualities of fruits and vegetables grown in the polluted soil.

Common pollutants from different sources

These include petroleum hydrocarbons, organic and inorganic solvents, pesticides and polycyclic aromatic hydrocarbons (PAHs). Exposure of petroleum hydrocarbon into the environment occurs either due to human activities or accidentally causing environmental pollution. This is caused mainly by accidents on oil platforms and ships used for hydrocarbon transportation but also by discharging water into the sea which is used to wash tanks of tanker vessels. Crude oil and petroleum products form a waterproof film on water that prevents the oxygen exchange between environment and water causing damages to plants, animals, and human beings. Petroleum hydrocarbon cause many toxic compounds which are potent immune-toxicants and carcinogenic to human beings. PAHs are ubiquitous environmental pollutants generated primarily during the incomplete combustion of organic materials (*e.g.*, coal, oil, petrol and wood).

Heavy metals

Metal having specific gravity of more than 5 or having atomic number higher than 20, *e.g.*, Arsenic, Cd, Zn, Hg, Ni, Cu, Fe, Pb, Mn, chromium, cobalt, gallium, gold, platinum, silver *etc.* (Alloway, 1990). Heavy metals may also present in crude oil, and its heavy metal content is associated with porphyrins which is the pyrrolic structure.

- Total wastewater generated from major industries (83, 048 Million Litre Day^{-1})
- The first largest contributor is thermal power plant (16, 348 MLD)
- The second largest contributor is engineering industries
- Major polluting industries are electroplating units, steel plants, textile industries, tanneries, mining *etc.*

Table 2: Heavy metal concentration range and limit (mg kg^{-1}) in soil

Elements	**Concentration range (mg kg^{-1})**	**Limit (mg kg^{-1})**
Lead	1-6900	600
Cadmium	0.1-345	100
Arsenic	0.1-102	20
Chromium	0.005-3950	100
Mercury	0.001-1800	270
Copper	0.03-1550	600
Zinc	0.15-5000	1500

Salt *et al.*, 1995

Toxicity symptoms of heavy metals in plants

- **Aluminum toxicity:** Stunted Growth, leaves turn dull green, often with small necrotic areas near tips and margins.
- **Cobalt toxicity:** Severe stunted growth; young leaves show chlorosis.
- **Chromium toxicity:** Growth stunted; younger leaves show chlorosis.
- **Copper toxicity:** Severe stunted growth; young leaves show chlorotic.

Different approaches/possible solutions for remediation of soil pollutants

1. Soil Washing
2. Pyrometallurgical Extraction

3. Vitrification/Solidification
4. Phytoremediation
5. Use of Humic Substances

Soil washing

It is a technology that uses liquids (usually water, sometimes combined with chemical additives) and a mechanical process to scrub soils. This scrubbing removes hazardous contaminants and concentrates them into a smaller volume. Hazardous contaminants tend to bind, chemically or physically, to silt and clay. Silt and clay, in turn, bind to sand and gravel particles. The soil washing process separates the contaminated fine soil (silt and clay) from the coarse soil (sand and gravel). When completed, the smaller volume of soil, which contains the majority of the fine silt and clay particles, can be further treated by other methods (such as incineration or bioremediation) or disposed of. The clean, larger volume of soil is not toxic and can be used as backfill.

The process works by either dissolving or suspending contaminants in the wash solution. The principle of soil washing lies on the fact that we are able to separate two fractions clean and polluted.

Description of the process

- First Soil is excavated.
- The soil is then sieved to remove debris and large objects such as rocks, which can be disposed of onsite if free from contamination.
- The smaller size of sand and gravel enters a soil washing unit or scrubbing unit, in which soil is mixed with washing water.
- The wash water is then drained from the washed soil.
- The soil is then rinsed with clean water.
- After washing, the heavier sand and gravel are allowed to settle.
- If clean, the sand and gravel are put back into the ground.

Pyrometallurgical technologies

Use of elevated temperature extraction and processing for removal of metals from contaminated soils. Soils are treated in a high-temperature furnace to remove volatile metals from the solid phase. Subsequent treatment steps may include metal recovery or immobilization. Pyrometallurgical treatment requires a uniform feed material for efficient heat transfer between the gas and solid phases and minimization of particulates in the off-gas. This process is usually preceded by physical treatment to provide optimum particle size. Pyrometallurgical processes usually produce a metal-bearing waste slag, but the metals can also be recovered for reuse.

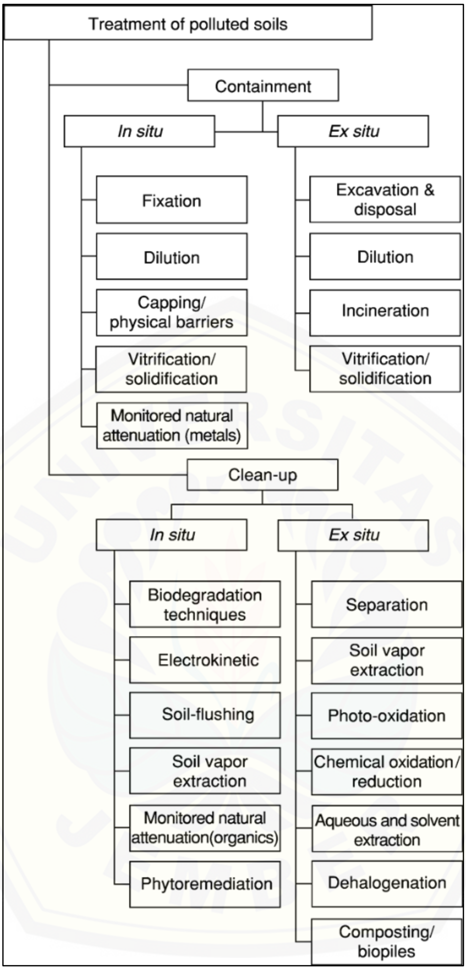


Fig 1: Flow chart for pyrometallurgical extraction of pollutants from the soil

Immobilization

To reduce the mobility of contaminants by changing the physical or leaching characteristics of the contaminated matrix. Mobility is usually decreased by physically restricting the contact between contaminants and surrounding groundwater, or by chemically altering the contaminant to make it more stable with respect to dissolution in groundwater. The aqueous and solid phase chemistry of metals is conducive to immobilization by these techniques.

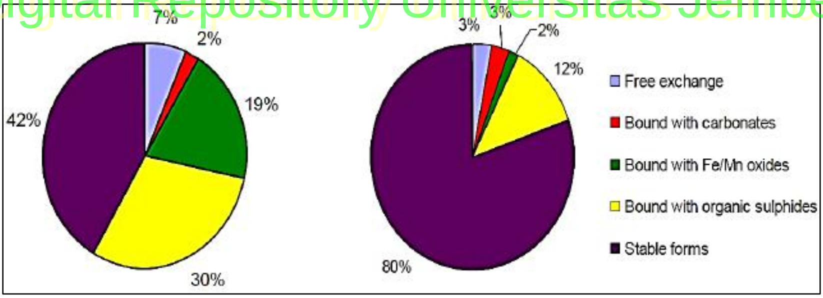


Fig 2: (a) Forms of copper in sandy loam soil with no amendments of HS (b) Forms of copper sandy loam soil with HS solution (20 g L^{-1})

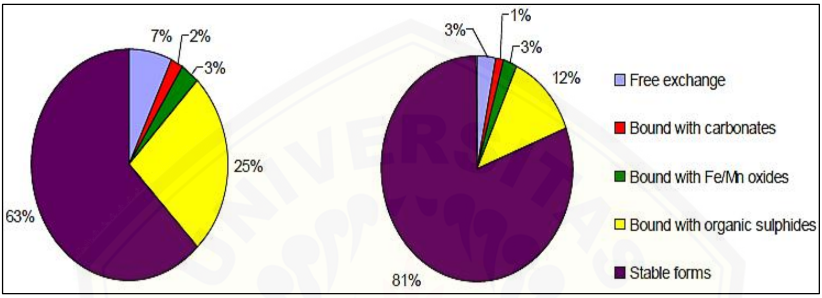
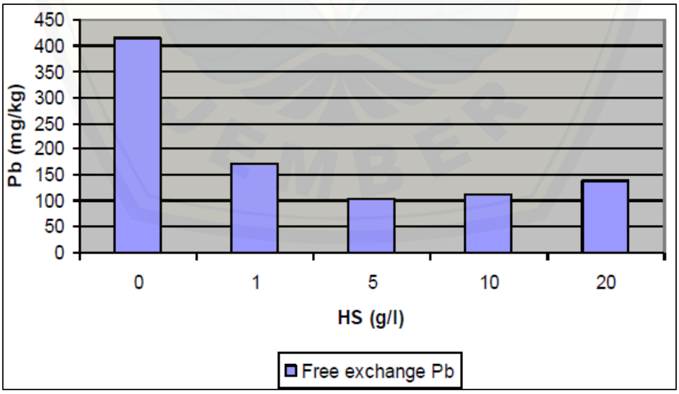


Fig 3: (a) Forms of copper in sandy loam soil with no amendments of HS (b) Forms of lead sandy loam soil with HS solution (20 g L^{-1})

(Burlakovs *et al.*, 2013)



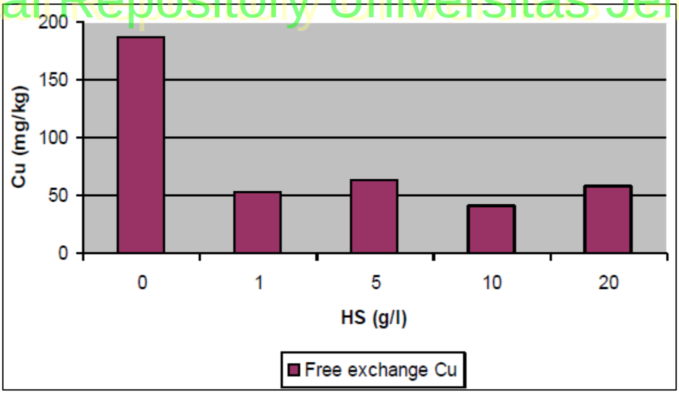


Fig 4: Free exchange lead and copper in sandy soil with various HS solution amendment (0-20 g L^{-1})

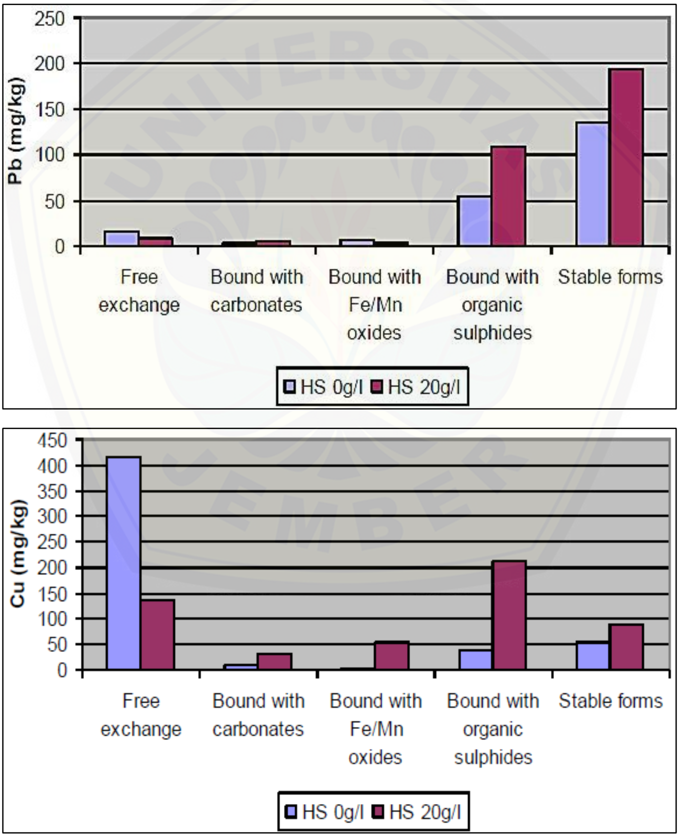


Fig 5: Forms of lead and copper in sandy soil with various HS solution amendment (0 and 20 g L^{-1})

(Burlakovs *et al*., 2013)

From the above Figures, it was concluded that increasing amount of HS additives allow to diminish the amount of copper and lead ions which are biologically available and increase the stable metal complexes. In order to characterize the interaction of HS with heavy metals, it is essential to assess the factors which determine the process of binding. Influential factors include, soil texture and mineral composition and the process is dependent on the type of soil, as well as ability of soil-forming minerals interacting with both metals and HS. Amount of free exchangeable copper and lead cations is generally decreasing, the trend go upwards if the amount of HS amended is increased up to 20 g L^{-1} (Figure. 2). Increasing concentration of HS increase with organic matter and sulphides associated and stable forms in soil. Significant increase of HS amount in sandy soil decreases easily available free exchange forms (Figure. 3). Metals in the Ap horizon during the time of 4 months has been bound in more stable complexes than at the beginning before the HS amendment.

Solidification and stabilization (S/S)

Immobilization technologies are the most commonly available options for metals-contaminated sites. Solidification involves the formation of a solidified matrix that physically binds the contaminated material. Stabilization, also referred to as fixation, usually utilizes a chemical reaction to convert the waste to a less mobile form. The general approach for solidification/stabilization treatment processes involves mixing or injecting treatment agents to the contaminated soils. Inorganic binders, such as cement, fly ash, or blast furnace slag, and organic binders such as bitumen are used to form a crystalline, glassy or polymeric framework around the waste. The dominant mechanism by which metals are immobilized is by precipitation of hydroxides within the solid matrix.

Vitrification

The mobility of metal contaminants can be decreased by high-temperature treatment of the contaminated area resulting in the formation of vitreous material, usually an oxide solid. During this process, the increased temperature may also volatilize or destroy organic contaminants or volatile metal species (such as Hg) that must be collected for treatment or disposal. Most soils can be treated by vitrification and a wide variety of inorganic and organic contaminants can be targeted. Vitrification may be performed ex situ or in situ, although in situ processes are preferred due to the lower energy requirements and cost.

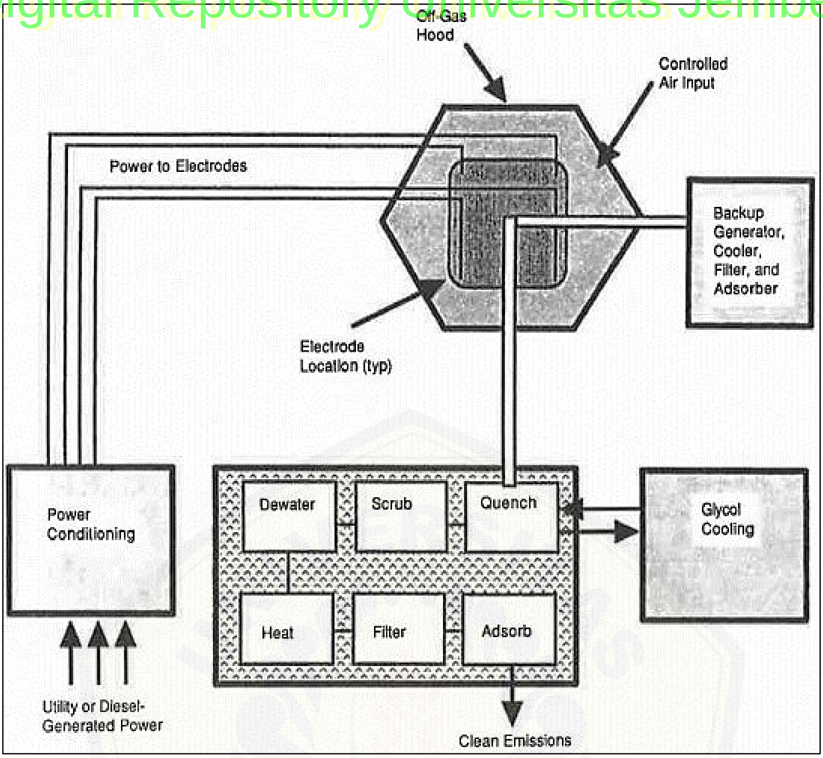


Fig 6: Flowchart of vitrification process

Among all these practices, phytoremediation can be used effectively but it takes much higher time. It can be used for both organic and inorganic pollutes of solid or liquid. Various phytoremediation strategies are possible for the remediation of heavy metal contaminated soils.

Different phytotechnologies make use of different plant properties

1. Phytoextraction
2. Phytodegradation
3. Rhizofiltration
4. Phytostabilization
5. Phytovolatilization
6. Use of Humic substances

Phytoextraction: The term “phytoextraction” mainly concerns the removal of heavy metals from soil by means of plant uptake. This technology is based on the capacity of the roots of plants to absorb, translocate and concentrate toxic metals from soil to the aboveground harvestable plant tissues.

Phytodegradation: The use of plants and associated microorganisms to degrade organic pollutants to less toxic forms or rendering them immobilized to prevent their entry in to the food chain or environment.

Rhizofiltration: It is defined as the use of plants to absorb, concentrate and precipitate contaminants from the polluted aqueous sources. It can partially treat industrial discharge, agricultural runoff or acid mine drainage.

Phytostabilization: The use of plants to reduce the bio availability of pollutants in the environment through reduction of leaching, run off and soil erosion. Prevent migration to the ground water or air.

Table 3: Hyper accumulators used for reclamation

Elements	**Plant species**	**Maximum conc. (mg kg^{-1})**
Cadmium	*Thlaspi caerulescens*	500
Chromium	*Brassica juncea, Helianthus annus*	1400
Nickel	*Alyssum lesbiacum, Sebertia accumulate*	47000
Lead	*Thlaspi rotundifolium, Brassica juncea, Zea mays*	8200
Cobalt	*Haumaniastrum robertii*	10000
Zinc	*Thlaspi caerulescens, Brassica juncea, B. oleracea, B. campestris*	51000
Selenium	*Brassica juncea, B. napus*	900
Copper	*Ipomoea alpina*	12000

(Shi and Cai, 2009)

Phytovolatilization: The chemical conversion of toxic elements into less toxic and volatile compounds is a possible strategy for detoxification of metal ion contaminants, resulting in the removal of specific harmful volatile elements (Hg and Se) from soil and plant foliage to the atmosphere. For example, the volatilization of Se involves the assimilation of inorganic Se into the organic selenoaminoacids selenocysteine and selenomethionine. The latter can be biomethylated to form dimethyl selenide, which is volatile and can be lost to the atmosphere.

Table 4: Concentration (mg kg^{-1}) of heavy metals in *Lemna minor* and *Azolla pinnata* before and after phytoremediation

Heavy metals	***Lemna minor***		***Azolla pinnata***	
	Initial conc.	**Final conc.**	**Initial conc.**	**Final conc.**
Mn	0.669	5.185*	0.568	4.903*

Cu	0.274	1.428*	0.015	0.817*
Zn	0.204	0.550*	0.030	0.628*
Fe	0.626	1.128*	0.816	1.225*
Pb	0.01	0.480*	0.10	0.382*
Cr	0.030	0.071*	0.031	0.092*
Cd	0.022	0.027*	0.016	0.030*

(Vaseem and Banerjee, 2012)

Humic substances

They are the general category of naturally synthesized, biogenic & heterogeneous organic substances that can generally be characterized as being yellow to black in colour, of high molecular weight and refractory.

Humin: That fraction of the humic material that is insoluble in water at all pH values

Humic acid: A mixture of weak aliphatic (carbon chains) and aromatic (carbon rings) organic acids which are not soluble in water under acid conditions but are soluble in water under alkaline conditions

Fulvic acid: It is a short chain molecule, which is low in molecular weight, yellow in color and soluble in all pH conditions

Table 5: Results of Initial Respirometric Tests with Artificial Sewage

Additive	**Concentration (mg L^{-1})**		**Humate Dose (mg L^{-1})**	**Removal (%)**	**Oxygen Uptake (mg O_2 L^{-1})**
	Initial	**Final**			
Phenol	500	290	0	42	140
	500	108	100	78.4	156
	500	58	200	88.4	164
	500	36	500	92.8	168
	500	22	1000	95.6	170
	500	4	2000	99.2	172
Copper	100	92	0	8	118
	100	68	100	32	125
	100	39	200	61	138
	100	22	500	78	148
	100	11	1000	89	156
	100	6	2000	94	162
Mineral oil	1000	900	0	10	138
	1000	720	100	28	146

	1000		360	200	64	153
	1000		195	500	80.5	162
	1000		105	1000	89.5	170
	1000		25	2000	97.5	174
Control	NA		NA	NA	NA	180

(Jan and Wayne, 2011)

Mechanisms involved in interaction of HS with molecules

Electrostatic attraction: Interaction between positively charged molecules and negatively charged HS (electrostatic attraction). Ex: interaction between HS and atrazine at pH=8.

Hydrogen bonding: The hydrogen bonding reactions are possible, involving oxygen, and nitrogen-containing functional groups of both HM and organic solute.

Example: interaction between carbaryl (an insecticide) and HM

Salt linkage or salt bridge: It is formed between the negative surface charge of HM and the negatively charged organic solute.

Example: Interaction between 2,4-dichlorophenoxyacetic acid (2,4-D) and HM molecules at pH 6-8. At this pH, both HM and 2,4-D are negatively charged.

Hydrophobic interactions: The interaction of non-polar molecules with HM is occurred via hydrophobic-hydrophobic interactions. The non-polar molecules will interact with the non-polar part (or hydrophobic part) of HM. An example on this mechanism is the interaction between DDT with HM.

Factors affecting complexation of metal

- **Nature of the bond formed:** Cu^{2+} and Pb^{2+} form Covalent bonds and Ca and Mg ionic.
- **pH value:** At low pH, H ions will compete with metals and decrease metals complexation.
- **Ionic strength:** Ionic strength of solution is inversely related to the complexation.
- **Availability of functional groups:** The maximum complexation occurs at 1:1 ratio of functional groups & metal ions.

Conclusion

Humic substances can significantly reduce the acute toxicity of metals and bioavailability of metals in soil as well as the effluents and have additional capacity to promote microbial activity. Although much remains to be studied, humic substances will clearly play a role in stabilization and remediation of many contaminated sites. This technology can reduce the total contaminant concentration with minimum cost. Thus, it is clear that the utilization of HS is going to help in cleansing the agro-ecosystem in future.

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Chapter - 5

Soil Erosion and Conservation Agriculture

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Chapter - 5

Soil Erosion and Conservation Agriculture

Sushila Aechra and Rashmi Bhinda

Abstract

Climate change and population are on the planet under immense pressure due to the continually increasing inadequate natural resources uses. Adverse natural activities and anthropogenic are the most important factors for the decline of natural resources. Water and soil are basic natural resources for the agricultural practices. Soil erosion is most severe threats for the deterioration of soil and water resources in different degradation processes. In India, water erosion degraded process posses about 68.4% of the total land area. Soil erosion process accelerates the by intensive agricultural operations. Likewise, depletion in groundwater level is resulted increased exploitation of groundwater. Therefore, the holistic management of water and soil resources is crucial for agricultural sustainability and security of the natural ecosystem. Adoption and development of better technologies, judicious use of natural resources and useful management practices are the basic need for protection of water and soil from degradation. This chapter point out the condition of natural resource degradation, erosion processes and soil and water conservation strategies for agricultural sustainability.

Keywords: agriculture, management, natural resources, soil erosion, water

1. Introduction

Soil is a dynamic natural body on the earth surface and is a critical resource for sustaining plant growth. The word "erosion" is derived from the Latin "erosio", meaning to "to gnaw away". In general terms soil erosion implies the physical removal of topsoil by various agents, including rain, water flowing over and through the soil profile, wind, ice or gravitational pull. The consequences of soil erosion can be seen both on-site and off-site. On-site effects are the loss of soil, the breakdown of the soil structure and a decline in organic matter. Erosion also reduces available soil moisture, resulting in more draught-prone conditions.

1. Soil erosion

Soil erosion is naturally occurring process that refers to removal of top soil by the action of water and wind during conversion of natural vegetation to agricultural land. The agents of soil erosion (water and wind) contributing a large amount of soil loss each year. The soil loss from agriculture land may be reflected in poor crop production potential, reduce surface water quality and destroyed drainage networks. Soil erosion is slow process that continues relatively unnoticed, or it occurs at an alarming rate causing serious loss of top fertile soil. The process of soil erosion is including three stages:

- **Detachment:** The topsoil is actually detached from the ground.
- **Movement:** The topsoil is relocated to the other area.
- **Deposition:** The topsoil ends after this process of movement.

There are certain factors that call accelerate erosion making it more noticeable and problematic. The susceptibility of soils to water erosion depends on:

- **Erodibility (Nature of the soil):** Is the ability to withstand raindrop impact.
- **Erosivity (Rainfall intensity):** High rainfall intensity creates serious risk as heavy drops on bare soil causes the soil surface to seal.
- **Slope steepness:** Runoff speed increases on steep slopes and increases the power of water to break off and carry soil particles.
- **Slope length:** If a slope is large water running down the slope moves faster and becomes deeper, taking more soil with it.

2. Types of soil erosion

Mainly there are two type of soil erosion.

A. Water erosion

It is the removal of soil from the land surface by water, including runoff from melted snow and ice and is one of the major causes of soil degradation. Water erosion has been sub divided into various types in relation to progressive concentration of surface runoff.

Forms of water erosion

1. Sheet erosion

It is the uniform deduction of surface soil in thin layers by sheet, or over land flow of water. The breaking act of rain drop combine with surface flow is the measure cause of sheet erosion. It is the first stage of erosion and is least conspicuous.

2. Rill erosion

When runoff starts, soil is lost from small but well-defined channels or streamlets (rills) by water when there is concentration of surface flow. This is the second stage of erosion. Rill erosion occurs while water runoff forms small channels and concentrates down a slope. These rills are able to be up to 0.3 m deep. If they become deeper than 0.3m they are known as gully erosion.

3. Gully erosion

Gully erosion happens when runoff concentrates and flow strongly enough to detach and move soil particles. Gullies may perhaps develop in water courses where runoff concentrates. In cultivation or grassland, advanced stage of rill erosion can develop into gully erosion. This type of erosion is highly noticeable and affects soil quality and productivity, restricts land use and can damage roads, buildings and fences. Gully depth is often limited by the depth of the underlying rock which means gullies are normally less than 2m deep. However, gullies may reach depths of 10–15m on colluvial and deep alluvial soils.

4. Stream bank erosion

Stream banks are eroded by water either flowing over the sides of stream or scouring at the base. The major cause of stream bank erosion is the destruction of vegetation on river banks (generally by clearing, overgrazing, cultivation, vehicle traffic up and down banks or fire) and the removal of sand and gravel from the stream bed.

Fig 1: Forms of water erosion

B. Wind erosion

Wind erosion is a serious environmental problem attracting the attention of many across the globe. It is a common phenomenon occurring mostly in flat, bare areas; dry, sandy soils; or anywhere the soil is loose, dry, and finely granulated. Wind erosion damages land and natural vegetation by removing soil from one place and depositing it in another. It causes soil loss, dryness and deterioration of soil structure, nutrient and productivity losses and air pollution. Suspension, saltation and surface creep are the three types of soil movement which occur during wind erosion. While soil can be blown away at virtually any height, the majority (over 93%) of soil movement takes place at or below one meter.

1. **Suspension:** Suspension occurs when very fine (less than 0.1mm) dirt and dust particles are lifted into the wind. They can be thrown into the air through impact with other particles or by the wind itself. Once in the atmosphere, these particles can be carried very high and be transported over extremely long distances. Soil moved by suspension is the most spectacular and easiest to recognize of the three forms of movement.
2. **Saltation:** The major fraction of soil moved by the wind is through the process of saltation. In saltation, fine soil particles (Less than 0.5 mm) are lifted into the air by the wind and drift horizontally across the surface increasing in velocity as they go. Soil particles moved in this process of saltation can cause severe damage to the soil surface and vegetation. They travel approximately four times longer in distance than in height. When they strike the surface again they either rebound back into the air or knock other particles into the air.
3. **Surface creep:** The large particles (Larger than 0.5-2.0 mm) which are too heavy to be lifted into the air are moved through a process called surface creep. In this process, the particles are rolled across the surface after coming into contact with the soil particles in saltation.

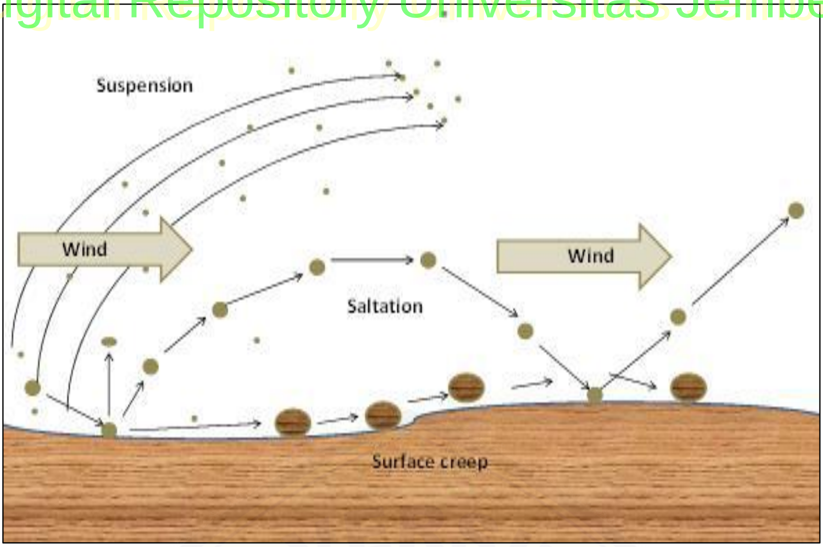

Fig 2: Types of wind erosion

3. Major effects of soil erosion

- **Removal of topsoil:** Topsoil is so fertile this can cause serious harm to farmer’s crops if it is removed and this is the major effect of soil erosion.
- **Poor drainage:** Sometimes more compaction with sand can increased to an effective crust formation, making it harder for water entry through to deeper soil layers. In some ways, because of the densely packed soil this can help erosion, other than if it perpetuates high levels flooding or rain water it can negatively impact the critical topsoil.
- **Plant reproduction issue:** When active cropland soil is eroded, wind in particular in lighter soil properties for example seedlings and new seeds to be destroyed and buried.
- **Soil compaction:** When soil becomes compacted and stiff under the topsoil, it decreased the ability for water to infiltrate and keeping runoff at higher levels, which improve the risk of more serious erosion.
- **Reduced organic and fertile matter:** By the removing of topsoil with heavy organic matter will decreased the capacity for the land to regenerate new life or crops.
- **Soil acidity:** When the soil structure is becomes compromised and

organic matter is greatly decreased, there is a more chance of increased soil acidity, which will considerably affect the ability for plants to grow and development.

- **Long term erosion:** The process of long-term erosion have already reduced the soil structure and organic matter of the area, importance that it will be harder to recover in the long run. If an area is highly prone to erosion it becomes harder to protect in the future.
- **Water pollution:** A major problem is that sediment and contamination like the use of fertilizers or pesticides causes the water pollution. This has large damage on water quality and aquaculture.

4. Consequences of soil erosion

Soil erosion has both offsite and onsite effect is the severest form of land degradation which has assumes nation as well as global importance. There are some consequences of soil erosion.

I. Land degradation
II. Soil degradation and loss in soil productivity
III. Floods and flood plains
IV. Siltation of reservoirs
V. Loss of biodiversity
VI. Environmental pollution
VII. Changing forest cover

5. Land degradation

Land degradation means loss in the capacity of a given land to support growth of useful plants on a sustained basis. Land degradation is a big loss to economy as the land loses its production potential and gets converted into wastelands. Hence shrinking of land resource base is a big problem before developing country like India. The per capita man land ratio in India is hardly about 0.48 hectare, which is lowest in the world.

Types of land degradation: Land degradation is categorized into three type’s i.e.

i) Physical degradation.
ii) Biological degradation.
iii) Chemical degradation.

Physical degradation refers to deterioration in physical properties of soil whereas biological degradation refers to reduction in soil organic matter, decline in biomass carbon and decrease in activity and diversity of soil fauna. Chemical degradation is basically due to the nutrient depletion.

Extent of land degradation: Degraded land includes eroded lands, saline/alkaline lands, water logged lands and mined lands. The total land area of India is 329 million hectares of which about 178 million hectares (54%) is converted into wastelands for one or other reasons. This also includes about 40 million hectares of degraded forest. The total cultivable land of the country is about 144 million hectares of which 56% (80.6 million hectares) is degraded due to faulty agricultural practices and the dense forest cover has been reduced to 11% (36.2 million hectares) of the total geographical area.

Table 1: Land degradation status in India

S. No.	Types of degradation(M/ha)	Area
1.	**Water erosion**	148.9
	1) Loss of top soil	132.5
	2) Terrian deformation	16.4
2.	**Wind erosion**	13.5
	1) Loss of top soil	6.2
	2) Loss of top soil/Terrian deformation	4.6
	3) Terrian deformation/Overblowing	2.7
3.	**Chemical degradation**	13.8
	1) Loss of nutrients	3.7
	2) Salinization	10.1
4.	**Physical deterioration (waterlogging)**	11.6
	Total degraded area	187.8

6. Conservation agriculture

Conservation agriculture is a set of soil management practices that reduced the disruption of the soils structure, compaction and natural biodiversity. The concept of conservation agriculture is comparatively using in new and modern cultivation practices. Conventional agricultural promote the widespread soil tillage, external inputs and burning of crop residues. These practices increased soil degradation by the loss of organic matter, compaction and soil erosion. In India nearly 70-75% farmers have small land holding they are still with traditional farm practices and play a major contributor in total food production. Majority of farmers have small interest to the long-term natural resources management and can hardly ever pay for input such as quality of seeds, heavy machines, fertilizer and herbicides for chemical weed management.

"Conservation agriculture (CA) aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. It can also be referred to as resource efficient or resource effective agriculture. (FAO)"

Aims of soil conservation

1) To protect the top soil from erosion.
2) To sustain the productive capacity of the soil.

7. Principles of conservation agriculture

The three key principles of CA are permanent residue soil cover, minimal soil disturbance and crop rotations.

1. Permanent or semi-permanent organic soil cover

In case of conventional farming, farmers burn or remove the crop residues or mix them into the soil with a plough or hoe. The soil is left bare, so it is easily washed away by rain, or is blown away by the wind. In conservation agriculture, crop residues left on the field, mulch and special cover crops protect the soil from limit weed growth and erosion throughout the growth period. Surface mulch helps decreased water losses from the soil by evaporation and also helps maintain soil temperature. This improves nitrogen mineralization and biological activity, particularly in the surface layers. A previous or cover crop residue not allowing weed seeds the light often needed for germination and help in decrease weed infestation through competition. The allelopathic properties of cereal residues in respect to check surface weed seed germination. Cover crops also improve biological soil tillage by their rooting growth; the surface mulch provides nutrients, food and energy for earthworms, arthropods and micro-organisms beneath ground that also known biologically till soils. Use of biological agents (earthworms, etc.) and deep-rooted crops also help to reduce compaction under zero-tillage.

2. Minimal soil disturbance

In conventional farming, farmers plough and disturb the soil as little as possible to control weeds and improve the soil structure. However in the long term, in fact destroy the soil structure and reduce the soil fertility. In conservation agriculture, tillage is reduced to ripping planting lines or making holes for planting with a hoe. The idea is to plant direct into the soil, without ploughing. Current agricultural practices and tillage operations reduced the organic matter due to increased oxidation over time, loss of soil biological fertility, leading to soil degradation and resilience. Although this SOM mineralization liberates nitrogen and can lead to improved yields over the short term, there is always some mineralization of nutrients and loss by leaching into deeper soil layers. This is particularly significant in the tropics where organic matter reduction is processed more quickly, with low soil carbon levels resulting only after one or two decades of intensive soil tillage. Zero-tillage, on the other hand, combined with permanent soil cover, has been shown to result in a build-up of organic carbon in the surface layers. No-tillage minimizes SOM losses and is a promising strategy to maintain or even increase soil C and N stocks.

3. Rotations

In conventional farming, the same crop is sometimes planted each season. That allows certain pests, diseases and weeds to survive and multiply, resulting in lower yields. In conservation agriculture, this is minimized by planting the right mix of crops in the same field, and rotating crops from season to season. This also helps to maintain soil fertility. Crop rotation is an agricultural practice with ancient origins. The different crop rotation with different rooting depth minimized the soil disturbance in zero-till systems and increase macro pores and network of root channels and in the soil. Crop rotations increase microbial diversity and reduce the risk of pests and disease outbreaks since the biological diversity helps check the pathogenic organisms. The discussion of the benefits of rotations will be handled in other chapters of this publication.

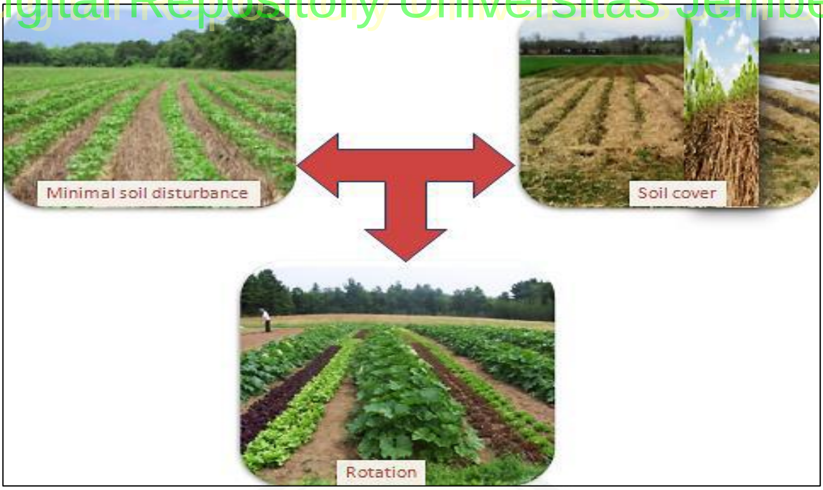

Fig 3: Principles of conservation agriculture

8. Soil and water conservation measures

Soil conservation is using and managing the land based on the capabilities of the land itself involving application of the best management practices leading to profitable crop production without land degradation. Soil and water conservation measures can be broadly grouped into three categories.

A. Agronomic practices.
B. Agrostological methods.
C. Mechanical Measures (Engineering Measures).

A. Agronomic practices

The important agricultural practices which contribute to the conservation and productivity of cultivated lands are referred to as conservation farming's or advanced agronomical methods.

i) Contour farming

It is practiced in the hilly regions or on the slopes. In such areas the rain water is absorbed in very little amount because of its quick downward movement on the slopes. If these sloppy areas are ploughed up and down the slope, the heavy rainfall may cause gully development. Taking into consideration this defect, the sloppy areas are ploughed and seeded against the slope, i.e., in circular furrows around the slopes. This process is termed as contour farming. Thus, contour farming reduces run off, saves more water for crops, reduces soil erosion and increases the yield of crops.

Fig 4: Contour Farming

ii) Tillage operation and keeping the land fallow

There are several diverse opinions as to whether deep ploughing gives good result or shallow ploughing. A number of researches support the view that in dry areas, shallow ploughing gives comparatively good crop yields. Shallow ploughing removes the weeds and enables the soil to absorb water. Deep ploughing or chiseling have been found effective in reducing erosion. Rough cloddy surface is also effective in controlling erosion. If the land is left uncultivated and sheep, goats and other cattle are allowed to graze and sit over it for some time, the soil becomes fertile. Though this practice is useful yet it is not possible in the countries like India where exists severe problem of cereals because of thick human population.

iii) Crop rotation and mixed cropping

Rotation of crops is an important method for checking erosion and maintaining productivity of soil. After 2 years crop should be changed in the fields. A good rotation should include a cultivated row crop, densely planted small grasses and a spreading legume or a legume and grass mixture. Selection of crops for rotation should be made taking into consideration the climate, economic condition, soil types, soil texture, slopes, nature of erosion, etc. Deep-rooted crops should be rotated by shallow-rooted crops. Deep-rooted crops absorb nutrients from the deeper strata of the soil Thus, the minerals o top soil remain stored for future use by shallow-rooted plants. When the deep-rooted crops le they add humus in the soil which is future storehouse of plant nutrients.

The rotation of crop serves the following purposes

a) Enriches the soil.

b) Improves the soil texture.

c) Improves water holding capacity of the soil.

d) Improves crop production.

e) Controls the recurrence of weeds and diseases.

Mixed cropping is another important method for increasing productivity of the soil. In this practice, one main crop and one or two subsidiary crops are grown together on the same land, as for example, growing of Arhar, Urad, Til along with millet. This practice checks the soil erosion and avoids the risk of crop failure. If one crop fails due to diseases or any other factor, the others remain ensured.

iv) Mulching

A mulch is plant residues or other material layer which natural or artificially applied on the surface of the soil with the object of moisture conservation, prevention of surface compaction or crust formation, temperature control, reduction of runoff and erosion, improvement in soil structure and weed control. It means covering the soil surface by straw, leaves or grasses. Mulches of different kinds check soil erosion, increase soil fertility and also minimize moisture evaporation from the top soils. Various types of surface tillers and crop residues are helpful in obstructing the movement of soil particles.

v) Strip cropping

This consists of growing erosion permitting crops and erosion resisting crops in alternate strips. The erosion permitting crops are cotton, jawar, bajara, etc. which allow the runoff water to flow freely within the rows. The erosions resisting crops are mostly legumes like groundnut, much (*Phaseolus aconitifolius*), hulgn (*Dolichos biflorus*), Soyabean (*Glycine max*) which spread and cover the soil and do not allow runoff water to carry much soil with it the soil which flows from the strips growing erosion permitting crops is caught by the alternating springs. It is an important method which employs all the advanced cultivation practices such as contour farming, proper tillage, crop rotation, mulching, cover cropping, etc. Strip cropping is very effective and practical means for controlling soil erosion.

Types of strip cropping

a) Contour strip cropping

It is special crops are grown on the strips across the slope on the level of contour and in the following season soil protecting crops are shown on the strips on which soil exposing crops were grown in the previous season and again in place of these soil protecting crops some soil exposing crops are sown. This practice is useful because it checks the flow of runoff water increases the infiltration of water in the soil and prevents soil erosion.

b) Field strip cropping

It is farming in more or less parallel strips across fairly uniform slopes but not on the exact contour.

c) Wind strip cropping

In this method tall growing plants (e.g. bajra, jowar, etc.) alternating with the short growing crops, such as 'arhar', 'urad' are sown in long straight strips right across the direction of wind regardless of contour.

d) Permanent or temporary buffer strip cropping

This is a special type of contour strip cropping in which care is taken to check the soil erosion. In this, crop rotation practice is not applied and on the strip perennial legumes and grasses are planted on permanent or temporary basis.

Fig 5: Types of strip cropping

B. Agrostological methods

The following are the important agrostological practices that check soil erosion:

1) Cultivation of grasses (ley farming).
2) Retiring the land.
3) Afforestation and Reforestation.
4) Checking of overgrazing.

1. Cultivation of grasses (Ley farming)

This method consists in growing grasses in rotation with agricultural crops. This practice improves the fertility of soil and helps in binding of the soil, thus preventing the soil erosion. This practice is recommended for Nilgiris and similar places which are subjected to very severe soil erosion.

2. Retiring the land

Areas subjected to heavy soil erosion should necessarily be put under thick cover of grasses. Under favourable climatic conditions grazing should also be allowed for short periods. Researchers conducted at Solapur in Maharashtra have shown that grasses have good soil binding capacity. In Nilgiri hills, Tamil Nadu doob grass (*Cynodon dactylon*), *Dectylis glomerata*, *Eragrostis amabilis* and *E. chebula* are proved to be most effective in soil binding and in stabilizing the reserves of the bench terrace and sodding water channels.

3. Afforestation and reforestation

Afforestation means growing forests at places where there were no forests before due to lack of trees or due to adverse factors such as unstable soil, aridity, or swampiness. Reforestation means replanting of forests at places where they have been destroyed by uncontrolled forest fires, excessive felling and lopping. Plantation of trees in short blocks is known as a wind break and extensive plantation of trees is called shelter belts. Wind is a problem in dry areas. Soil erosion by wind can be checked or reduced if the soil is covered by vegetation. Wind breaks are planting of trees or other plants at right angles to prevailing wind that protect bare soil from full force of wind. Wind breaks reduce the velocity of wind, thereby decrease the soil erosion.

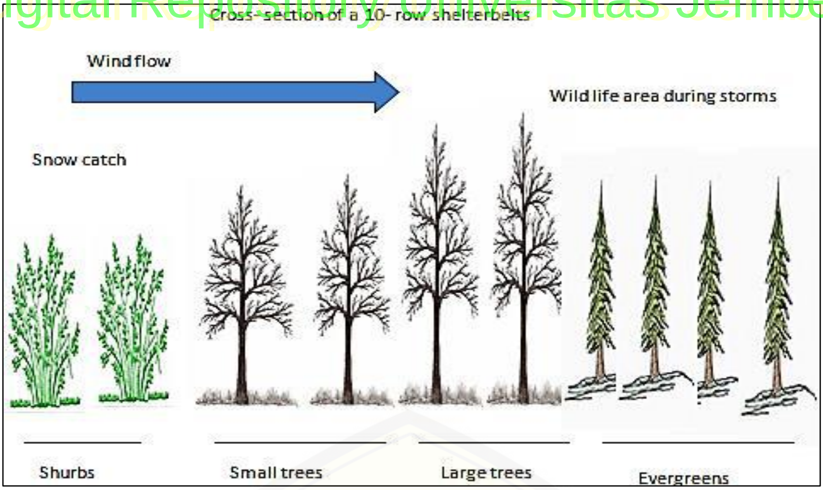

Fig 6: Shelterbelts effect

Afforestation is the best means to check the soil erosion. In the area where plantations have not been made the soil is actively eroding. Another example is afforded by Sankaracharya Hills in the vicinity of Srinagar which was heavily eroded in the past. It has now been improved by afforestation. Forest department took up the planting of conifer species like *Pinus wallichiana*, *P. roxburghii*, *P. sylvestris*, *P. insignis*, *P. gerardiana*, *Cupressus arizonica*, *C. sempervirens*, *Juniperus species*, *Cedrus deodara*, and broad-leaved species, like *Aesculus indica*, *Fraxinus*, *Juglans regia*. These plants check erosion to some extent. The efforts are being made to check the spread of Rajasthan desert towards Uttar Pradesh and the plantation is being done in that region in two or three belts. Small-sized plants are planted on the windward side and tall trees on the leeward side. On the windward side *Leptadenia spartium, Cenchrus ciliaris, Balanites roxburghii*, *Calligonum polygonoides*, *Saccharum munja*, *Kochia indica*, etc. are commonly planted and on leeward side *Acacia Senegal*, *A. leucophloea*, *Ricinus communis*, *Prosopis spicigera*, *P. juliflora*, *Parkinsonia*, etc. are being grown. The problem of afforestation is the selection of suitable species for a given area. This can be accomplished by dividing the whole area into different catchment zones according to climate, soil and biota. Suitable species for each zone should be selected from those already growing there. Knowledge of succession trends of the vegetation will be of great help in afforestation practices. The climax vegetation in any region is most effective agent to prevent accelerated erosion. Afforestation also checks the erosion of unstable rocks probably by checking the leakage of water.

4. Checking of overgrazing

Since grazing in all the areas subjected to soil erosion cannot be completely stopped, a system of restricted and rotational grazing may be helpful in checking soil erosion to some extent. The area open to grazing for sometimes should be closed for the following years to facilitate regeneration of forest and to maintain thick ground vegetation.

C. Mechanical methods (engineering measures)

It is only in recent years that soil erosion problems have received attention of engineers. The mechanical practices of soil conservation include various engineering techniques and structures which are adopted to supplement the biological methods when the latter alone are not sufficiently effective.

These practices aim at the following objectives

1) To reduce the velocity of run-off water and to retain it for long period so as to allow maximum water to be absorbed and held in the soil.
2) To divide a long slope into several small parts so as to reduce the velocity of run-off water to the minimum.
3) Protection against erosion by wind and water.

Mechanical methods for soil conservation are

i) Basin leaching

In this method, a number of small basins (water reservoirs) are made along the contour by means of an implement called basin blister. Basins collect and retain rain water for long period and also catch and stabilize downwardly moving soils of the slopes.

ii) Pan breaking

In some areas, soils become impervious to water and are less productive because of formation of hard sheet of clay a few feet below the surface. Such areas can be made productive and water permeable by breaking hard clay pans by means of pan breaker on contour at a distance of about 5 feet. By pan breaking, drainage and percolation of rain water is improved and soil is saved from residual run-off and erosion.

iii) Sub-soiling

In this method hard subsoil is broken deeply by means of an implement called subs oiler. This process promotes absorption of rain water in the soil and makes the soil looser and more fit to allow luxuriant growth of vegetation.

iv) Contour terracing

Sometimes drainage channels or properly spaced ridges or soil mounds are formed along the contour (at right angles to the slope) to retain water in the soil and check the soil erosion. These are called terraces. Terraces are leveled areas constructed at right angles to the slope to reduce soil erosion.

Terracing may be of the following four types

a) Channel terracing

This is concerned with making of wide but shallow channels on contours at suitable distance. In this process, the excavated soil is deposited along the lower edge of channel in the form of low ridge.

b) Narrow based ridge terracing

This process is commonly called bunding. In this a number of narrow based ridges or bunds are constructed at distance of 1into 2inacross the slope along the contour.

c) Broad-based ridge terracing

In this, wide but low bunds are made on contour by excavating soils from both the sides of ridge.

d) Bench terracing

This method involves making of wide step like platforms, the so-called bench terraces, having suitable drops along contours. Along the outer edges of bench terraces bunds of about one foot height are raised to check the downward flow of rain water and also soil erosion. The vertical drops may vary from 1into 2 m. Bench terracing is very costly process and so it should be applied in the area of land scarcity for growing money crops.

Terracing is the only practical method of soil conservation on steep land. It is an expensive method or reducing soil erosion since it requires moving soil to construct the leveled areas, protecting the steep areas between terraces and constant repair and maintenance. Many factors such as length, the steepness of slopes, type of soil, and amount of precipitation determine the feasibility of terracing.

v) Contour trenching

This method involves making a series of deep pits (2′ x 1′) or trenches across the slope at convenient distance. The soil excavated from the trenches is deposited along the lower edge in the form of bund. On the ridges tree seeds are sown.

vi) Gully and ravine control

It is the advance stage of water erosion. Size of the unchecked rills increases due to runoff. Gullies are formed when channelized runoff from vast slopping land is sufficient in volume and velocity to cut deep and wide channels. Ravines are prolonged process of gully erosion, typically find in deep alluvial soils. They are deep and wide gullies indicating stage of gully erosion.

vii) Ponds and reservoirs

Small ponds and water reservoirs or dams should also be made at suitable places for irrigation and some other purposes. Various types of dams have been devised to arrest and plug gullies and thus to check soil erosion.

These dams may be

a) Brush dams
b) Earth dams
c) Concrete dams
d) Woven wire dams

viii) Stream bank protection

Banks of ravines and rivers with high vertical drops are subjected to heavy soil erosion. The bank erosions can be checked by making the drop slopy and by growing vegetation on the slopes or by constructing stone or concrete pitch.

9. Conclusion

The land is diminishing and finite regularly due to the increasing varied kind of degradation and therefore is no choice to expend cultivable land area. Availability of water and healthy soil are essential for productivity in terrestrial ecosystems because plants need fertile soil with good quality of irrigation water and improved soil properties for their growth and development. Use of water and soil conservation practices including biological and mechanical is imperative to decrease runoff losses, soil erosion and to improve water quality, soil quality, moisture conservation, and crop productivity in a sustainable manner.

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Chapter - 6

Nitrogen Fixation Enhancement in Pulses under Moisture Stress Condition by Foliar Application of KNO_3

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Chapter - 6

Nitrogen Fixation Enhancement in Pulses under Moisture Stress Condition by Foliar Application of KNO_3

Dr. Amita Singh

Abstract

Aim: Biological nitrogen fixation is an important aspect in crop production. Pulses gained importance in the global agriculture because of their high protein content and also for their inherent capability of fixing atmospheric nitrogen. The aim of this chapter is to highlight the effect of water stress on the nodulation, protein content and its impact on seed yield of the test crop, *Vigna mungo* and mitigation of adverse effect of water stress by foliar application of KNO_3.

Method: The inoculated seeds Vigna mungo (L.) Hepper or Black gram (Urd) were sown in earthenware pots (30x 30 cm) containing garden soil 4kg. The plants were irrigated with ground water at 1,3,5 and 7 days interval drought (DID) up to 25 DAS. Control plants were watered at regular intervals. The effect of foliar application of 200ppm KNO_3 was also studied along with different treatments of water stress up to 25DAS. Morphology of nodule (i.e. no. of nodule, shape, size and colour of nodule) and protein content were recorded at every ten day interval from day 25 up-to day 55 each treatment and also in combination with foliar application of 200 ppm KNO_3.

The plants were harvested after 90 days and the following parameters were studied for yield.

1. Nitrogen content.
2. Protein content.

Result: In KNO_3 treated plants, the size of nodule increased and plants nodules are mostly pink in colour. The capacity for protein synthesis decreased considerably in response to water stress. Protein synthesis increase in KNO_3 treated plants. The result indicates that moisture stress adversely affected protein content in seed. Yield improvements observed in potassium treated plants. Adequate potassium nitrate helps in increasing crop tolerance to water stress and promotes root growth that results in better uptake of nutrients and led to improvement of the protein as compared to control. KNO_3 have better impact on mitigating stress because interaction of Nitrogen and Potassium during formative phases and seed-filling stages give higher yield.

Conclusion: Increased application of potassium has been shown to enhance photosynthetic rate, plant growth, plant yield and drought resistance in pulse crops under water stress conditions. Potassium mitigates the adverse effects of water stress by favourably influencing internal tissue moisture, photosynthetic rate & Nitrogen metabolism

Keywords: agriculture, KNO_3, nodulation, nitrogen fixation, *Vigna mungo*

Introduction

Approximately 72% of cultivated land in India is rain fed largely due to an inadequate precipitation and erratic rainfall resulting in reduced crop. In the post green revolution period, water stress problem is a major concern affecting the agriculture production. Generally pulses are very susceptible to water stress. Agele *et al*., 2006) Pulses gained importance in the global agriculture for their high protein content and also for their inherent capability of fixing atmospheric nitrogen through symbiotic root nodule bacteria of the genus *Rhizobium* (Ravichandran and Pathmanabhan, 2004). Competition with high yielding variety of cereals has shifted pulses to marginal lands. To increase the present yield level understanding various physiological process which are negatively affected due to drought condition is a matter of great concern. Among the pulses *Vigna mungo* (L.) Hepper or Black gram (Urd) is the most important pulse crop being sown commonly as a mixed crop subsidiary to cotton, maize or jowar. Urad dal is a prebiotic food due to its high content of amylose starch “Prebiotics" is food ingredients which cannot be digested with our normal digestive process but require the help of stomach bacteria to digest. It also stimulates growth of good bacteria in the digestive system.

Poor monsoon and extended dry condition during critical growth period have a devasting influences on the crop performance. The production of the urd could not be increased per unit area because even today 60-70% of the crops are grown under rain fed condition. High yields under such conditions need extra supply of nitrogen. Potassium, being a major plant nutrient, which influences the water economy and crop growth through its effects on water uptake, root growth, maintenance of turgor, transpiration and stomatal regulation (Nelson,1980). Moreover, adequate potassium nutrition helps in increasing crop tolerance to water stress and promote root growth and results in better uptake of nutrients and water (Polizotto, 1986 and Umar *et al*. 1990).

In recent years, numbers of chemicals are directly sprayed on foliage of the crop plants, because they are readily absorbed and utilized more efficiently than soil application.

The aim of the present investigation was to study the effect of water stress on Nodulation, the Nitrogen and protein content of leaves and its impact on seed protein of the test crop Vigna mungo. Soil moisture deficiency has a pronounced effect on N2-fixation, nodule initiation, growth and activity are all sensitive to water stress. (Albrecht *et al*. 1994).

The effect of water stress on nodulation and nitrogen fixation depends on the growth stage of the plants. It was found that water stress imposed during vegetative growth was more detrimental to nodulation and nitrogen fixation than that imposed during the reproductive stage. Nitrogen is one of the essential nutrients for plants and its practical management as the major element in intensive agriculture for plant production is an important aspect. An optimally adequate supply of nitrogen is required to be maintained throughout crop growth for better plant yield and crop production. Nodulation, nitrogen activity and dry matter yield increased with incremental K+ supplied plants.

Material and methods

The seeds of *Vigna mungo* (L.) Hepper or Black gram (Urd) were surface sterilised with ethanol for 5 minutes followed by thorough wash with distilled water. Surface sterilized seeds 200 in number of Vigna mungo were inoculated by keeping them dipped in 96 hour old culture of Rhizobium phaseoli and of equal densities 0.05 OD at 610 nm for 12 hour at 25 °C to30 °C.

The inoculated seeds were sown in earthenware pots (30x30cm) containing garden soil 4kg. The plants were irrigated with ground water at 1,3,5 and 7 days interval drought (DID) up to 25 DAS. Control plants were watered at regular intervals.

The effect of foliar application of 200ppm KNO_3 was also studied along with different treatments of water stress up to 25DAS.

Morphology of nodule (i.e., no. of nodule, shape, size and colour of nodule) and protein content were recorded at every ten-day interval from day 25 up-to day 55 each treatment and also in combination with foliar application of 200 ppm KNO_3.

For measurement of protein content in dried leaves and seed the amount of insoluble nitrogen fraction, as obtained by micro kjeldahl digestion method was multiplied by a factor 6.25.

The plants were harvested after 90 days and the following parameters were studied for yield.

3. Nitrogen content.
4. Protein content.

The experiment culture was carried out in completely randomized design (CRD). Each treatment was analysed with at least 5 replicates and standard deviation (SD) was calculated.

Results

Number of nodule increased from day 25 to 55 days at the rain fed condition in all the stages in both variable moisture regimes. Nodule number decreased with foliar application of KNO_3. (table-1) Nodules are separated and rounded in control and mild stressed plants. They are aggregated and globose, club-shaped, indeterminate in moderate stressed plants. Nodules are not distinct in severely stressed plants; they are fused with root and give tuberous appearance of the roots in 400 ml(table-2) Size of nodules ranges from 2mm-5mm in stressed plants. In severe stressed plants, nodules are numerous in number, and enormously fused with root and could not be measured. In KNO_3 treated plants, the size range increased from 7mm-10mm. (Table-3) Nodules are pink colour in control and mild stressed plants. In moderate stressed plants, nodules are slightly pink in colour. In severe stressed plants, nodules are white in colour. KNO_3 treated plants nodules are mostly pink in colour. Colour intensity more increased in KNO_3 treated plant. (Table-4).

The capacity for protein synthesis decreased considerably in response to water stress. The decreased protein content could be due to decrease in protein synthesis and oxidative injury in response to water stress, which involves the formation of activated oxygen species and its subsequent reaction with macromolecules such as protein and lipids. A reduction in protein content has been shown to be associated with sensitivity of the cultivars to drought (Deka and Baruah, 2000). Protein synthesis increase in KNO3 treated plants.

Yield attributing parameters like total nitrogen content and protein content were studied in T9 variety. These parameters correlated well with the activities of enzymes and bio chemical estimations and also with the morphological characters of plants. The result indicates that moisture stress adversely affected protein content in seed. Though moisture was the limiting factor but this could be overcome to a certain extent by potassium application in the entire situation (Mengel and Brunschweig 1972) have also reported the significance of potassium under dry conditions. Similarly Rama Rao (1986) also observed favourable effects of potassium on pearl-millet yield under moisture stress situations. Yield improvements due to potassium application in number of crops have been reported (Sharma *et al*. 1992, Umar *et al*. 1993). Mengel and Kirkby (1980) suggested that under low soil moisture, K-application may result in yield improvement. Lahiri (1980) found increase shoot and seed yield with increasing K- levels, even under acute soil moisture deficit in moth bean, mung bean and cluster bean. Singh *et al*. (1997) reported favourable effects of potassium applications on chickpea yield under water stress at various developmental stages.

Table 1: *Vigna mungo*: Number of nodule at different age of growth in black gram under water stress (day) and also treated with KNO_3

Para-meters	**Amount of water**	**Number of nodule**		**Para-meters**	**Amount of water**	**Number of nodule**	
	(ml)	**Without treatment**	**With KNO_3 treatment**		**(ml)**	**Without treatment**	**With KNO_3 treatment**
25 DAS	Control	16±2.86*	19±1.78*	45 DAS	Control	23±1.22	29±3.19
	1Day	20±0.70	23±2.12		1Day	30±2.49	25±1.08
	3Day	25±1.08	25±2.49		3Day	32±2.49	28±0.70
	5Day	28±0.70	26±1.78		5Day	35±1.78	29±2.49
	7Day	29±1.41	27±1.41		7Day	33±1.08	29±1.22
35 DAS	Control	20±1.47	19±2.95	55 DAS	Control	26±1.41	32±2.12
	1Day	28±0.70	24±2.70		1Day	32±2.16	26±1.78
	3Day	30±1.08	26±2.70		3Day	33±0.71	28±2.12
	5Day	32±0.70	28±3.09		5Day	33±2.86	30±1.08
	7Day	34±1.47	28±2.70		7Day	31±1.41	29±1.22
*Mean ± Standard deviation N=3)							

Table 2: *Vigna mungo*: Shape of nodule at different age of growth in black gram under water stress (days) and also treated with KNO_3

Parameters	**Amount of water**	**Spherical/Rounded**		**Elongated/Loaded**		**Clump/Aggregated**		**Fused/Tuberous**	
	(ml)	**Without Treatment**	**With KNO_3**	**Without Treatment**	**With KNO_3**	**Without Treatment**	**With KNO_3**	**Without Treatment**	**With KNO_3**
25 DAS	Control	+	+	-	+	-	-	-	-
	1 day	+	+	-	-	+	+	-	-
	3day	-	+	-	-	+	-	-	-
	5day	+	-	+	-	-	-	+	-
	7 day	-	-	+	-	-	+	-	-
35 DAS	Control	+	+	-	-	-	+	-	-
	1 day	+	+	+	-	+	-	-	-
	3day	-	+	+	-	-	-	-	-
	5day	-	-	-	+	+	+	+	-
	7 day	-	-	-	+	+	+	+	-
45 DAS	Control	+	-	+	+	-	+	-	-
	1 day	-	+	+	-	-	-	-	-
	3day	-	+	+	-	+	+	-	-
	5day	-	-	+	+	-	+	-	-
	7 day	-	-	+	+	-	+	-	-
55 DAS	Control	-	-	+	+	-	-	-	-
	1 day	-	-	+	-	-	+	-	-
	3day	-	-	+	-	-	+	-	-
	5day	-	-	-	-	-	+	+	-

	7 day	-	-	-	-	-	+	+	-
*Mean ± Standard deviation (N=3)									

Table 3: Vigna mungo: Nodule Size at different age of growth in black gram under water stress (days) and also treated with KNO_3

Para-meters	**Amount of water**	**Large (7 to 10 mm)**		**Medium (5 to 7 mm)**		**Small (2 to 5 mm)**		**Minute (1 to 2 mm)**	
	(ml)	**W/O Treatment**	**With KNO_3**	**W/O Treatment**	**With KNO_3**	**W/O Treatment**	**With KNO_3**	**W/O Treatment**	**With KNO_3**
25 DAS	Control	+	+	+	+	+	-	-	-
	1 day	+	+	+	+	+	-	-	-
	3day	+	-	+	+	+	+	-	-
	5day	-	+	-	+	+	+	+	-
	7 day	+	-	-	+	+	+	+	-
35 DAS	Control	+	+	+	+	-	-	-	-
	1 day	+	+	+	+	-	+	+	-
	3day	-	-	+	+	+	+	+	-
	5day	-	-	+	+	+	-	-	-
	7 day	-	-	-	+	+	+	+	-
45 DAS	Control	-	+	+	+	-	+	-	-
	1 day	-	-	+	+	-	-	-	-
	3day	-	+	+	+	-	+	+	-
	5day	-	-	+	+	+	+	+	+
	7 day	-	+	-	+	+	+	+	+
55 DAS	Control	+	+	+	+	-	-	-	-
	1 day	-	+	+	+	-	-	-	-
	3day	-	+	+	+	-	+	-	-
	5day	-	+	+	+	-	-	+	+

	7 day	-	-	+	+	-	-	+	+
*Mean ± Standard deviation (N=3); W/O – Without									

Table 4: *Vigna mungo:* Nodule colour at different age of growth in black gram under water stress (days) and also treated with KNO_3

Parameters	**Amount of water**	**White**		**Light pink**		**Pink**	
	(ml)	**without treatment**	**With KNO_3**	**without treatment**	**With KNO_3**	**without treatment**	**With KNO_3**
25	Control	+	-	-	-	+	+
	1 day	-	-	+	-	+	+
	3day	-	-	+	-	-	+
	5day	+	-	+	-	-	+
	7 day	+	-	+	-	-	+
35	Control	-	-	+	-	+	-
	1 day	-	-	-	+	+	+
	3day	-	-	+	+	-	+
	5day	-	-	+	+	-	+
	7 day	+	-	-	+	-	+
45	Control	-	-	-	+	+	-
	1 day	-	-	+	+	-	-
	3day	-	-	+	+	-	-
	5day	+	-	-	+	-	-
	7 day	+	-	-	+	-	-
55	Control	-	-	+	+	-	-
	1 day	-	-	+	+	-	+
	3day	-	-	+	+	-	-
	5day	+	-	-	+	-	-
	7 day	+	-	-	+	-	-
*Mean ± Standard deviation (N=3)							

Photograph of nodule of black gram showing effect of potassium on size of nodule. 1- With potassium 2- Without potassium.

Fig 1: Effect of potassium on nodule size

Photograph of nodule of black gram showing effect of potassium on size of nodule. 1- Water logging, 2- Control, 3- Water deficit.

Fig 2: Effect of potassium on shape and arrangement of nodule

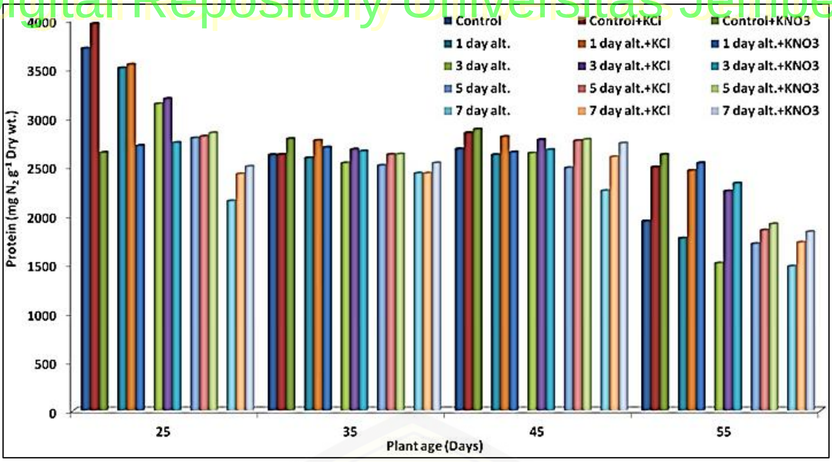

Fig 3: *Vigna mungo*: Protein content in leaf at different age of growth in black gram under water stress (days) and also treated KNO_3

Table 5: *Vigna mungo*: Nitrogen and Protein content in seed of black gram under water stress (days) and also treated with KNO_3

Water Treatment (Days)	Nitrogen content (mg/g dry wt)		Protein content (mg N2 g-1 Dry wt)	
	Without Treatment	With KNO_3	Without Treatment	With KNO_3
Control	28.59±0.18*	33.62±0.10*	171.87±0.24*	199.37±0.13*
1Day	24.68±0.05	31.52±0.06	153.75±0.31	188.75±0.24
3Day	23.98±0.07	31.2±0.04	149.5±0.20	187.5±0.20
5Day	23.55±0.04	28.92±0.05	146.87±0.18	178.12±0.13
7Day	21.54±0.03	28.77±0.02	134.37±0.25	174.2±0.15

Discussion

The result of the present investigation indicates that water stress has adverse effect on Nodulation, Protein content (Fig-A) and yield of the test plant Vigna mungo. Number of root nodule is of the important factors which determine the nitrogen fixing ability of the plants. Water stress adversely affected the nodulation pattern of root in Black gram (Table-1). Reduced water potential checks Rhizobium infection (Worrall and Roughley1976) and nodule development (Galiacher and Sprent 1978). Drought may induce senescence in the developed nodule. An indeterminate type of nodule exhibits considerable resistance to water stress ((Engin and Sprent 1973), Wahab and Zahran, 1979) while spherical or determinate type nodules are less resistant (Sprent, 1976). In the present work, number of nodule decrease in KNO3 treated plants. KNO_3 stimulated nodule growth (Picture 1 and 2) which may perhaps be due to fact that KNO_3 seemed to increase the activities of the enzymes in the rhizosphere. KNO_3 promote the growth and development of nodule, this is due to adequate potassium nitrate helps in increasing crop tolerance to water stress and promotes root growth that results in better uptake of nutrients and water (Polizotto, 1986 and Umar *et al*. 1990). It has been demonstrated that nodular development may be reversible until the moisture content of the nodule falls below 80% under water stress (Swaraj *et al*. 1984). The result of the present investigation indicates that water stress has adverse effect on yield of the test plant Vigna mungo. Applied K mitigates the adverse effects of water stress in Black gram by favourably influencing internal tissue moisture photosynthetic rate and nitrogen metabolism and increase yield (Table-5).

Applied K mitigates the adverse effects of water stress in Black gram by favourably influencing internal tissue moisture photosynthetic rate and nitrogen metabolism.KNO_3 have better impact on mitigating stress because interaction of N and K during formative phases and seed-filling stages give higher yield.(Majumdar *et al*. 1980) The extent of change in any plant process mainly depends on the severity and duration of water stress and also on the stage of plant development when the water stress has occurred.(Kramer,1983).

Conclusion

[*Vigna mungo* (L.) Hepper], Blackgram is important pulse crop having protein content 24-28% and rich in phosphate. Combine effect of high temperature and low moisture can be alleviated by increasing the concentration of potassium in the soil. Increased application of potassium has been shown to enhance photosynthetic rate, plant growth, plant yield and drought resistance in pulse crops under water stress conditions. Potassium mitigates the adverse effects of water stress by favourably influencing internal tissue moisture, photosynthetic rate & Nitrogen metabolism.

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