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Standardization of measures to overcome the ill effects of water logging stress conditions for cotton, maize and sunflower crops of vertisols

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Abstract
A field experiment was conducted for three kharif seasons (2014, 2015 & 2016) at Regional Agricultural Research Station, Nandyal, Andhra Pradesh to study the ill effects of waterlogging stress conditions on yield attributes, seed yield, benefit cost ratio and available soil nutrient status of three crops viz, Cotton, Maize and Sunflower. Higher yields of maize, sunflower and cotton crops under ridge and furrow method with nutritional management practices recorded 4260, 652 and 835 kg/ha respectively. The study indicated that along with planting methods like Broad bed furrow (BBF), Ridge & Furrow methods (R&F) along with nutrient management practices like Urea Application of @ 50 Kg/ha along with spraying of liquid fertilizers like Multi K (13-0-45) & Urea solution @ 2% and Gypsum application @ 500kg/ha at critical stages of crop will lead you for crop sustainability and maintaining the available N, P and K of soil, leading to positive nutrient balance. Measures to ameliorate the ill effects of waterlogging stress conditions will lead to enhancement of productivity of rainfed crops besides relieving distress among farmers when high rainfall situations occur.

Keywords: Ill effects, water logging condition, abiotic stress, b:c ratio-vertisols

Introduction

Water logging in vertisols has been identified as a major abiotic stress that has marked effect on plant growth and development including survival of plants in extreme cases. It drastically influences that soil physico-chemical properties, most notable soil redox potential, pH and oxygen levels. Thus, condition of hypoxia (deficiency of oxygen) and anoxia (absence of oxygen) are commonly encountered by the plant root systems. Under such situations, understanding the plant behavior and finding out the ways to ameliorate the water logging stress conditions will help for sustainable rainfed agriculture even when crops is exposed to high rainfall situations, especially in vertisols. Oxygen deficiency inhibits the root respiration of plants which results in substantial reduction in energy status of root cells. Since oxygen is a terminal electron acceptor in aerobic respiration, in its absence, Kreb's cycle and electron-transport system are blocked. Therefore, plants under waterlogged conditions use alternate pathway for energy extraction. This alternate pathway uses fermentative metabolism to produce Adenosine triphosphate (ATP), thereby, resulting in enhanced accumulation of ethanol (Muhammad Arslan Ashraf 2012) [7].

Recently Shraf *et al.* (2011) reported that exogenous application of potassium in soil and as foliar spray alleviated the adverse effects of water logging on cotton plants. Conaty *et al.* (2008) reported that leaf SPAD readings nitrogen and potassium concentrations were reduced in waterlogged treatments compared to respective controls, and varied with cotton cultivar. Leaf phosphorous, calcium, magnesium, manganese and sulphur concentrations were reduced in waterlogged treatment compared to respective cultive controls in all cultivars. However, water logging increased the leaf total iron concentrations in all cultivars. Bange *et al.* (2003) reported that a single waterlogging event during early squaring and five events throughout growth of the same cumulative duration in cotton gave the same impact on lint yield. However, when the single event was imposed at peak green bolls, it had no significant effect on yield. No impact of water logging on fibre quality was detected.

Submerging soil and chemical fertility

The most important influence of submerging a soil in water is to reduce oxygen supply. As a result, the entrained oxygen is quickly exhausted (Ponnaperuma 1972 & 1984). The lack of free oxygen or anaerobiosis causes soil reduction and sets in motion a series of physical, chemical and biological processes. The influence of flooding on physical, chemical and electrochemical properties of soil has been comprehensively researched and reviewed from time to time. The main electrochemical changes that influence the chemistry and fertility of submerged soils and growing of crops such as sunflower, maize & cotton were

- A decrease in redox potential (redox potential, Eh) or reduction of the soil.
- An increase in pH of acid soils and a decrease in pH of alkali soils, and changes in the floodwater pH.
- An increase in specific conductance and ionic strength of soil solution.
- Ionic equilibria influence sorption–desorption reactions and the availability of major and micronutrients (Sahrawat, K. L 2004) [15].

Michael Bange *et al.* (2004) [5] reported that cotton yield was strongly related to the number of days when air filled porosity of the soil (proportion of air present in the soil) at a depth of 10 to 20 cm was below (0.1 cm3 of air/cm3 of soil or 10% air by volume). However, where certain agronomic practices were employed, no effects on yield and fibre quality were seen even when the crop had been inundated continuously for 72 hours. Water logging early in crop growth had far greater influence on yield than water logging at mid flowering or later. Water logging is the major obstacle for sustainable agriculture. Plants subjected to water logging suffer from substantial yield losses. It is also known to induce adverse effects on several physiological and biochemical processes of plants by creating deficiency of essential nutrients like nitrogen, magnesium, potassium, calcium (Muhammad Aslan Ashraf, 2012) [7]. Likewise, reduced endogenous levels of N, P and K have been reported in maize by Atwell and Steex (1990)

Ashraf and Rehman (1999) reported that application of nitrate in soil proved useful in mitigating the harmful effects of water logging on different physiological attributes of maize. Flooding causes greater crop yield losses when it occurs early in the season (Lizaso and Ritchie, 1997). When six inch corn was flooded 24, 48 and 72 hours, corn yields were reduced N level, these reductions ranged from 18 to 14% in one year and 5% in another year. When corn at a height of 30 inches was flooded for 24 hours and 96 hours, yields were reduced 14 to 30% with a high level of N in soil, very little yield reduction occurred even with 96 hours flooding. When flooded near silking, no reduction in yield occurred at a high N level, but yield reductions up to 16% occurred with 96 hours of flooding at the low level of N.

When five irrigation treatments (0, 2, 6 and 24 hour ponding in furrows plus a h hour flooded treatment) were applied at first two irrigations after emergence of a maize crop, there was no difference between 2,6 and 24 hour furrow treatments in any of the maize parameters measured, indicating that a threshold level of water logging was reached in all three compared with zero ponding treatment. Individual plants within the treatment population differed greatly in their response to the water logging and the effect on individual plant persisted until final harvest (Mason *et al*, 1987). Ajaz A. Lone and M.Z.K. Warsi, 2009 [1] stated that flooding at knee height stage of the crop growth resulted in immediate wilting of plants starting from the base of the plant and subsequent loading of most of the plant. In leaves, wilting started from the tip and proceeded towards the base of the leaf. In most of the genotypes anthesis silking interval got widened even more than eight days in some cases was recorded, which subsequently resulted in barrenness of plants and reduction of overall yield (Trought, M.C.T., Drew, M.C., 1982) [20].

Waterlogging during grain filling of sunflower determines direct physiological response that decreases grain yield. These response, modulated by the environment conditions prevailing during and after waterlogging, include negative effects on plant leaf area, leaf capacity to fix carbon and plant capacity to absorb water (Patricio Grassini *et al*., 2007) [9]. In Sunflower, leaf expansion and extension were inhibited by waterlogging at 6-leaf and bud visible stage although these effects did not always persist until maturity while, with anthesis waterlogging, rapid desiccation of leaves was observed. Yield was most affected by waterlogging at anthesis but no consistent effect on seed number or 1000 seed weight was recorded (Orchard and Jessop, 1984) [8]. Measures to ameliorate the ill effects of waterlogging stress conditions will lead to enhancement of productivity of rainfed crops besides relieving distress among farmers when high rainfall situations occur. (Ashraf 2009 and Ashraf M, Akram NM (2009) [3, 4].

Methodology

A field experiment was conducted for three continuous kharif seasons of 2014, 2015 & 2016 at Regional Agricultural Research Station, Nandyal, Andhra Pradesh to study the ill effects of waterlogging stress conditions on yield attributes, seed yield, benefit cost ratio and available soil nutrient status of three crops viz, Cotton, Maize and Sunflower. The soil of experimental site was medium deep black, clayey, low in organic carbon (0.36%) & low in Nitrogen (140kg/ha) high in available P_2O_5 (58.65 kg ha^{-1}) and available K_2O (435 kg ha^{-1}).

Normally, Rayalaseema region of Andhra Pradesh is known for dry climate and drought situations. Rainfall received is continuos for kharif season and waterlogging situation is very rare in this zone. But due to climate change and global warming, August and September months were receiving high rainfall which leads to waterlogging situation in most of the zone. There are some recommendations to follow some agronomic practices and application of some nutrients either through top dressing or through foliar spray. However systemic studies are lacking on the effect of water logging stress at different stages of rainfed crops and their ameliorations. To overcome the waterlogging situation in vertisols, we proposed this project of three continuous Kharif seasons of 2014, 2015 & 2016 with the following treatments at RARS Nandyal.

Different Management Practices will be taken up whenever the crop is exposed to water logging stress(Natural/ Simulates)

Design: Split-Plot
Replications: Non Replicated
Main plots: Management practices

M1: Control (Without management under water logging condition)

M_2: Agronomic Management (Repeated inter cultivation coupled with weed management)

M_3: Draining of excess moisture (coupled with weed

Management)

M4: Rainfed crop

M5: Nutrient Management (Urea Application of 50 Kg/ha along with Spraying of liquid fertilizers like Multi K (13-0-45) & Urea @ 2% and Gypsum application @ 500kg/ha)

Sub plots: Land management practices like three planting methods

a. Broad bed furrow
b. Flat bed furrow
c. Ridge and furrow

Sub-Sub Plots

S_1: Cotton
S_2: Maize
S_3: Sunflower

Objectives of the study were

1. To study the effect of water logging stress conditions at different stages of important rainfed crops of vertisols in terms of growth, yield and nutrient deficiencies.
2. To find out the ways to ameliorate the water logging stress effects on rain fed crops of vertisols.
3. To develop a package for rainfed crops of vertisols, proned to water logging conditions.

The plot size was 9mx3m and spacing of 60cmx30cm. Waterlogging stress was imposed at vegetative stage i.e at 21DAS, two days for one treatment from 21-22 DAS and four days for another treatments from 21to 24 DAS and control plants were maintained under normal irrigation conditions. Waterlogging was administered by applying heavy irrigation to the plots assigned to the waterlogging treatments. Soil was kept saturated with the water above field capacity by continuous flooding, usually every day twice to create an oxygen deficiency environment. The crops were grown following the recommended package of practices and timely plant protection measures were also adapted. Sampling was done at 25, 35,45,55,65 DAS. Five plants from each treatment were dugout along with roots and separated into leaf, stem, root and pods and dried at 80^{o}c temperature in a hot air oven until constant weight was attained. The dry weight of leaf, stem, pods and roots of the plant was recorded separately.

Results

The results were depicted in Table 1 to 4**.** In *Kharif,* 2014-15, among 3 planting methods crop growth is highest in Ridge &Furrow method, followed by Broad Bed Furrow and Flat method. Among all the treatments, Nutrient management treatment recorded highest yield in Sunflower(8.17 q/ha), maize crop (75q/ha) and in Cotton (25 q/ha).Soil and plant samples were analysed for nutrient status at different stages of crop growth. There was no much variation in the nutrient status with respect to soil sample. However, plant sample analysis indicated that out of three stages viz., vegetative, flowering and maturity, flowering stage was found to be slightly affected with water logging where in lower values for major plant nutrients (NPK) were recorded. Same results were also reported by Saritha B and Singh BB (2002) [13].

In *Kharif* 2015-16**:** During 2015-16 Maize crop under ridge and furrow method with nutritional management practices recorded 7854kg/ha yield, net returns Rs 53204/ha with C:B ratio 1:3.0. under water logging condition raising of crops in ridge and and furrow and adopting nutritional management practices cotton and sunflower crops recorded an yields of 729,1123 kg/ha respectively. Prasanna Y.L. and Ramarao G. 2014, were also reported similar results in Green gram crop.

In *Kharif* 2016-17**:** Higher yields of maize, sunflower and cotton crops under ridge and furrow method with nutritional management practices recorded 4260, 652 and 835 kg/ha respectively. These results were in accordance with the Yadav DK and Srivatava JP (2010) [21].

Table 1: Effect of different agronomic practices under ill effects of water logging stress conditions on crop yields in vertisols at the end of *kharif*-2016-17

Treatment	Yield kg/ha		
	Cotton	**Maize**	**Sunflower**
Control (water logging): Broad bed and furrow	475	2935	396
Ridge and furrow	580	3150	367
Flat bed	440	2985	524
Agronomic practice: Broad bed and furrow	610	5035	628
Ridge and furrow	835	4260	652
Flat bed	580	3600	570
Nutrient Management: Broad bed and furrow	795	6450	771
Ridge and furrow	855	7520	817
Flat bed	673	5170	785
Rainfed crop: Broad bed and furrow	460	3685	485
Ridge and furrow	558	4460	450
Flat bed	400	4115	686
Drainage: Broad bed and furrow	515	5445	480
Ridge and furrow	485	6350	585

Table 2: Cotton Economics

Cotton Economics	Seed Cotton Yield Kg/ha	Gross returns Rs/ha	Net returns Rs/ha	C:B
Control (water logging) Broad bed and furrow	384	16148	-	1:0.5
Ridge and furrow	405	17045	-	1;0.6
Flat bed	363	15251	-	1;0.5
Agronomic practice Broad bed and furrow	619	26016	-	1:0.8
Ridge and furrow	747	31399	3399	**1;1.1**
Flat bed	448	18839	-	1;0.6

Nutrient Management Broad bed and furrow	704	29604	104	1:1
Ridge and furrow	769	32296	3796	**1;1.1**
Flat bed	577	24222	-	1;0.8
Rainfed crop: Broad bed and furrow	384	16148	-	1:0.5
Ridge and furrow	513	21530	-	1;0.8
Flat bed	192	8074	-	1;0.3
Drainage: Broad bed and furrow	363	15251	-	1:0.5
Ridge and furrow	449	18839	-	1;0.6

Table 3: Maize Economics

Maize Economics	GrainYield Kg/ha	Gross returns Rs/ha	Net returns Rs/ha	C:B
Control (water logging) Broad bed and furrow	3200	38400	13400	1:1.5
Ridge and furrow	3478	41736	17736	**1:1.7**
Flat bed	3018	36216	14216	1:1.6
Agronomic practice Broad bed and furrow	5552	66624	40624	**1:2.5**
Ridge and furrow	4492	53904	28904	1:2.1
Flat bed	3822	45864	22864	1:1.9
Nutrient Management Broad bed and furrow	6642	79704	53204	1:3.0
Ridge and furrow	7854	94248	68748	**1:3.6**
Flat bed	5369	64428	40928	1:2.7
Rainfed crop: Broad bed and furrow	3842	46104	22104	11.9
Ridge and furrow	4652	55824	32824	1:2.4
Flat bed	4324	51888	30888	1:2.4
Drainage: Broad bed and furrow	5641	67692	42192	1:2.6
Ridge and furrow	6526	78312	53812	**1:3.2**

Table 4: Sunflower Economics

Sunflower Economics	Seed Yield Kg/ha	Gross returns Rs/ha	Net returns Rs/ha	C:B
Control (water logging) Broad bed and furrow	488	18056	-	1;0.7
Ridge and furrow	487	18019	-	1;0.7
Flat bed	508	18796	-	1;0.8
Agronomic practice Broad bed and furrow	781	28897	2897	1;1.1
Ridge and furrow	866	32042	7042	1;1.6
Flat bed	735	27195	4195	1;1.8
Nutrient Management Broad bed and furrow	921	34077	7577	1;1.2
Ridge and furrow	1123	41551	16051	1;1.2
Flat bed	733	27121	3621	1;1.2
Rainfed crop: Broad bed and furrow	686	25382	1382	1;1.1
Ridge and furrow	800	29600	6600	1;1.5
Flat bed	745	27565	6565	1;1.3
Drainage: Broad bed and furrow	713	26381	881	1;0.7
Ridge and furrow	1038	38406	13906	1;0.8

Conclusion
The study indicated that along with planting methods like Broad bed furrow (BBF), Ridge & Furrow methods (R&F) along with nutrient management practices like Urea Application of @ 50 Kg/ha along with spraying of liquid fertilizers like Multi K (13-0-45) & Urea solution @ 2% and Gypsum application @ 500kg/ha at critical stages of crop will lead you for crop sustainability and maintaining the available N, P and K of soil, leading to positive nutrient balance.

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