Response of Alfalfa and Sorghum to P Fertilization In Muwaqqar Soil at Field Capacity

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Ashraf M. Al-Baqain

عميد كلية الدراسات العليا

Supervisor

Dr. Ibrahim Ghawi

Co. Supervisor

Dr. Butros Hattar

Submitted in Partial Fulfillment of The Requirements for the
Degree of Master of Science in
Soil and Irrigation

Faculty of Graduate Studies
The University of Jordan

August 1998

This thesis was successfully defended and approved on August, 4, 1998.

Committee Members	Signature
1. Dr. Ibrahim O.Ghawi Associate professor of Soil physics (Chairman of committee)	I. O. Ghawi
2. Dr. Butros I. Hattar Associate professor of Soil Fertility (Member of Committee)	BI Hattar
3. Dr. Abdel Nabi Fardous Soil Physicist, National Center for Agricultural Research and Technology Trasfer (NCARTT) (Member of Committee)	
4. Dr. Hani Saoub Assisstant Professor of Forage crops (Member of Committee)	Hani Saoub
5. Dr. Richard Dunham Soil and Water Management Specialist (Member of Committee)	Richard Dunham

Dedication

To the Moon ....

☞My Mother

To the Sun ....

☞ My Father

To the Stars ....

☞My Brothers and Sister

To the honest men .....

☞My comrades

ACKNOWLEDGEMENT

I wish to express my deep appreciation and thanks to my advisor Dr. Ibrahim O. Ghawi for his care and orientation throughout the field work and production of this thesis.

Appreciations and thanks are also extended to Dr. Butros. Hattar, Dr. Abdel Nabi Fardous, Dr. Hani Saoub and Dr. Richard Dunham members of the committee for their valuable comments.

Grateful Acknowledgements to JAZPP for their financial assistance, and to my best friend Mohammed Al-Qinna for his assistance.

Finally a big gratitude to all the members of the soil and irrigation department for their support.

Thanks should be given to all who helped, supported or advised me through this study.

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ABSTRACT

RESPONSE OF ALFALFA AND SORGHUM TO P FERTILIZATION IN MUWAQQAR SOIL AT FIELD CAPACITY

by

ASHRAF M. Al-BAQAIN

Supervisor

DR. IBRAHIM GHAWI

Co. Supervisor

DR. BUTROS HATTAR

1998

A field experiment was conducted during 1996/1997 at the University of Jordan Research Station near Al-Muwaqqar village to examine the possibility of planting forage crops (alfalfa and sorghum) in deep and shallow soil profile at field capacity and to study the effect of phosphorus fertilization on forage root growth.

Randomize complete block design was adopted in the experiment. Three rates of **P** fertilizer were used. Phosphorus application rates were 0 **(P1)**, 50 **(P2)**, and 100 **(P3)** kg TSP/ha.

In the shallow soil profile, alfalfa root depth increased at **P3** compared to **P1** and **P2**. Alfalfa root depths were 0.70, 0.60 and 0.45 m under **P3**, **P2**, and **P1**, respectively. In the deep soil profile, alfalfa roots were found at depths where wetting front existed because of high initial available **P** in soil. Alfalfa root depths were 1.05, 0.90 and 1.05 m in **P3**, **P2**, and **P1**, respectively.

In deep soil profile, sorghum root depth improved at **P3** level compared to **P1** and **P2** levels. Sorghum root depths were 0.90, 0.75 and 0.75 m under **P3, P2,** and **P1** levels, respectively. In shallow soil profile, sorghum root depth reached the end of the soil profile (0.70m) under **P3** and **P2** phosphorus levels, while sorghum root depth was 0.60 m under **P1** level. Alfalfa and sorghum total root length increased at **P3** compared to **P1** and **P2** at both deep and shallow soil profiles.

In deep soil Profile, no significant differences in alfalfa evapotranspiration (ET) were found, while in shallow soil profile,there were significant differences in alfalfa ET as affected by different phosphorus levels. At both locations significant differences in sorghum ET as affected by different phosphorus levels were found.

In deep soil profile, there was no significant effect of **P** levels on alfalfa dry-matter yield, while in shallow soil profile, alfalfa dry-mater yield increased significantly under **P3** compared to **P2** and **P1** .

In deep soil profile, **P3** level produced significantly higher sorghum stover and grain yields compared to **P1**, Sorghum grain yield was 0.164, 0.067 and 0.041 ton/ha under **P3, P2** and **P1** respectively, while sorghum stover yield was 0.885, 0.551 and 0.370 ton/ha under **P3, P2** and **P1** respectively. In shallow soil profile, there was no significant effect of phosphorus on sorghum stover yield, and no grains were produced.

At both locations, no significant differences were found in residual phosphorus after alfalfa while residual **P**, in shallow profile after sorghum increased under **P3** (43.8 ppm) treatment compared to **P1** (8.2 ppm) treatment, while there was no significant differences in residual **P** between **P1** and **P2** and between **P2** and **P3**, while in deep soil profile there was no significant differences in residual **P** after sorghum among **P** treatments.

1. INTRODUCTION

Jordan is an arid country with limited surface and ground water resources. The Jordanian steppe is typical to the mediterranean arid region occupying a major portion of Jordan, where pricipitation is limited, erratic in distribution and highly variable with occasional storms of high intensities. Most rainfall is lost by evaporation and runoff due to unfavorable rainfall characteristics, soil surface properties, high temperature and scarce plant canopy. This land, with certain exception, was defined as range land, not to be cultivated. Cultivating such areas depends upon providing water for irrigation and preventing deterioration of soil properties. Soil surface crusting is a common problem in arid and semi-arid soils. It is considered a major cause for the reduction in both infiltration rate and hydraulic conductivity, increase in surface runoff, high erosion and lower water use efficiency of the land (Felhender et al., 1974; Frenkel et al., 1978; Bradford et al., 1987; and McIntyre, 1958a). Susceptibility to seal is an improtant common problem in many parts of the world. The problem is likely to be most severe in unstable soils of arid and semi-arid regions, where soil surface is characterized by low aggregate stability (Allison, 1956), high silt content (Evans and Boul, 1968; Cary and Evans, 1974), low organic matter (Ahmad and Roblin, 1971), and where irrigation and tillage practices are carried out (Hillel, 1960).

Jordan suffers from shortage in meat production, because of the lack of feed supplies required for livestock. Summer forage crops can be grown in arid and semi-arid areas wherever water is available. Production of summer forage crops decreases the expensive forages imports.

Al-Muwaqqar Station, where the study was conducted, has typical Mediterranean climate (wet winter and dry summer). Rainfall varies from 80 to 200 mm with an annual mean of 150 mm falling mostly in January and

February. Evaporation losses from soil surface and open water are important in terms of storage efficiency. Evaporation from bare soil surface ranges from less than 1 mm day^{-1} during winter to 10 mm day^{1-} during summer (Spoor, 1995). Water stored in the soil profile will lower surface evaporation losses, and allows 10%-15% of the total stored water to be stored until the following rainy season (Spoor, 1995)..

Water collected in small earthen dams during winter can be stored within soil profiles to produce summer forage crops such as sorghum and alfalfa without further irrigation. Using furrows increases infiltration (Akasheh, 1996) due to less silt action and less crusting on the sides of the furrows.

Phosphorus fertilizer application promotes root length (Coale and Grove, 1986), therefore, enhances utilization of water and nutrients at greater depths.

The objectives of this research are:

1- To examine the possibility of planting forage crops (sorghum and alfalfa) in soil profiles at field capacity.

2- To study effect of (P) fertilization on root growth of the two forage crops.

3- To find out if soil profile at Muwaqqar could be filled to field capacity by using deep contour furrows.

2. LITERATURE REVIEW

2.1 Alfalfa

Alfalfa is one of the most valuable and widely grown forage crop. It has been called "queen of forage crops" because of its remarkable ability to produce high yields of rich, palatable, nutritious forage under wide range of soil and climatic conditions. Alfalfa has relatively low production costs compared to perenials, supports symbiotic dinitrogen fixation, and provides favorable soil condition in crop rotation (James, 1988).

Fields in production for 10 or more years are quite common and average stand duration is estimated to be more than 5 years (Lowe et al., 1972).

Alfalfa is drought tolerant. The ability of alfalfa to withstand drought is attributed to its deep root system. Alfalfa exhausted soil moisture down to 2.1m in 2 years, to 4.6m at the end of 3 years, and to 7.6m at the end of 6 years (Jung and Larson, 1972). Fredricksen confirmed these observations and gave additional evidence that the high yield of alfalfa in dry areas was due to its deep root system. An extensive and deep root system, therefore, is important for survival in semi-arid areas because plants with shallow roots are unable to secure moisture from lower depths (Jung and Larson, 1972).

Numerous factors, such as temperature, available moisture, and salt concentration of the media surrounding the seeds, are known to influence germination of alfalfa seeds. The failure of an individual viable seed to produce a plant may be due to poor seedbed preparation, seeding too deep, inadequate moisture after germination, freezing, diseases, insects, competition for light and nutrients with other alfalfa seedling, the companion crop and weeds (Tesar and Jackobs, 1972). Sixty to seventy percent emergence in humid areas is considered excellent with good seeding techniques. The percentage of seedlings surviving the 1st year is generaly in the range of 40 to 50% of the seeds sown. Frequently, seedling survival is as low as 20% (Brown et al., 1960). Alfalfa may be seeded in a moist seedbed, or in dry soil and "irrigated-up" (Dennis et al., 1966). On a moist seedbed the seed should be placed deep enough to be in moist soil. If crust forms after irrigation, additional light irrigations may be necessary to soften the crust and permit seedlings to emerge (Tesar and Jackobs, 1972).Moisture content of the soil 24 hours after planting was significantly correlated with emergence (Triplett and Tesar, 1960). Available soil moisture greatly influences growth of alfalfa seedlings. Readily available soil moisture supply during the seedling stage is important (Bula and Massengale, 1972). Growth of both tops and roots of alfalfa seedling was reduced by increasing the moisture stress (Gist and Mott, 1958). Best growth obtained when 35 to 85% of the available moisture remained in the active root zone (Stanberry, 1955). Photosynthesis and respiration of alfalfa seedlings were not decreased until soil moisture dropped to about 35% of the maximum water-holding capacity (Murata *et al.*, 1966). Leaf water content did not change appreciably until soil moisture declined to 20% of the maximum water holding capacity. .

Transpiration rate of alfalfa was as high as for most crops under adequate moisture condition. James (1988) reported that evapotranspiration (ET) of well irrigated alfalfa in the arid region of southern Idaho, from April through October, averaged 1022 mm for three harvests per season when soil water was not a limiting factor. Water requirement for alfalfa was found to be 800 mm at 73% soil saturation and 1360 at 36% soil saturation (Gifford and Jensen, 1967). Jung and Larson (1972) estimated alfalfa water requirement to be between 800 and 900 mm. Cole et al., (1970) found differences in the water requirements within varieties as among varieties.

Water required was influenced by external environmental factors, such as temperature, evaporation, soil texture, soil salinity, depth and extent of root penetration, and source of water (Bolton, 1962). Established alfalfa obtained about 46% of its moisture from the top 2 feet (6.1 dm) of its root zone (Erie et al., 1968). Remaining moisture was obtained from each of three successive 2- feet increments of its root zone approximately as follows: 26, 18, and 10% respectively (Bula and Massengale, 1972). Taylor and Marble (1986) found that more than 95% of the soil water extracted by alfalfa was taken from 0-1.2 m depth and yield was reduced by water stress when most of the available water within the 0-0.6m depth had been used. Available water at this depth was mostly used within 12 days. Jung and Larson (1972) indicated that 46% of water absorbed by alfalfa was from the first 30.5 cm of soil, 22% from the second 30.5 cm and 10 % from each of the third, fourth, and fifth 30.5 cm of soil depth. However, these percentages could vary, depending on climatic conditions, depth and amount of roots within the soil profile, soil texture and perhaps other factors.

Temperature is a primary factor affecting seedling emergence. Generally, an increase in temperature, within limits, increases the rate of germination and emergence. Bula and Massengale (1972) indicated significant differences in rate of seeds germination among alfalfa cultivars at 5, 10, 15 and 20°C. Most rapid and vigorous seedling emergence occurred when daily mean air and soil temperatures were near 25°C. Seedling emergence and growth would be minimal under soil and air temperatures below 10°C or above 35°C (Bula and Massengale, 1972). Graza et al., (1965) reported that growth of seedling of 4 weeks age was better at 30 than at 15°C. Smith (1969) indicated that average shoot height was considerably greater for alfalfa plants grown in a cold environment (18 °C day/10°Cnight) than in warm environment (32 °Cday/24°C night). Plants growth in the cold environment developed more slowly and the first flowers appeared 2 weeks later than in plants grown in warm environment (Smith, 1969; and Smith, 1970). Alfalfa decreased in height and reached first flower earlier as temperatures increased during the season (Jensen et al., 1967; Smith, 1969; Smith, 1970, and Vough and Marten, 1971). Robison and Massengale (1968) reported a decline in forage production at each successive harvest from June to September. Rogers (1969) attributed the reduction in alfalfa yield growing at high temperature to the decrease in symbiotic N-fixation because of high soil temperature. Temperature effects on specific metabolic function, such as N-fixation or assimliation could intensify the deleterious effect of high temperatures and further reduce forage yield potential. Seedlings are susceptible to frost injury from the time cotyledons emerge from the soil until four or five leaves are formed (Jung and Larson, 1972). Water deficit and wilting in alfalfa could be caused by low root temperatures, eventhough water supply is not limiting (Ehrler, 1963).

Nitrogen is seldom applied to pure alfalfa stands except for a small amount at seeding time on soils low in organic matter because it is assumed that the symbiotic N-fixing bacteria in the nodules will supply adequate N. (Rhykerd and Overdahl, 1972). In general, N fertilization tended to decrease yield and stand and to increase weeds (Tesar and Hildebrand, 1966). Ward and Blaser (1961) indicated that alfalfa seedling number were reduced and seedling growth was not improved as rates of N were increased from 0 to 90 kg per hectare.

2.2 Sorghum

Grain and forage sorghums are important feed crops for the extensive cattle industry of the world. Depending on the cultivar, sorghum may be grazed or harvested for grain, hay, or silage (Paul, 1988). Sorghum grown for forage may be utilized as fodder, stover (fodder from which heads have been removed), silage, or hay, or may be grown as a soiling crop (cut and fed green) or for pasture. Also the heads may be fed as such, or they may be threshed and the grains used as feed. The feeding value of an acre of sorghum is about 50 percent higher when fed in the form of silage than as fodder. Sorghum grains are valuable for all classes of livestock and poultry. Ground grains are worth nearly 95 percent as much as corn, measured by livestock gains. Sorghum silage is highly palatable and nutritious. It is slightly lower in feeding value than corn silage (Martin and Stephens, 1955).

Sorghum is adapted to semi-arid regions. It also performs well on dry land, especially when soil water is not limiting at planting, and rainfall is near-normal during the growing season (Musick and Dusek, 1971; Unger, 1984; Unger and Wiese, 1979). Water stress at critical reproductive stages can sharply reduce grain yields of the crop in dry land (Paul, 1988). In contrast, forage sorghum has no such critical stages and hence, do not require such timely rainfall to attain good yields. Unger and Wiese (1979) indicated that sorghum grain yields on dryland, however, can be reduced sharply by water stress during critical reproductive growth stages (booting, flowering, grain filling) even though early growth may provide for near-normal stover production.

Sorghum is a warm weather crop. Planting should not be done until frost hazard is prevented and the soil is warm. Early planted sorghum often requires a longer time to reach maturity than those planted after conditions become favorable (Wesley, 1955).

Sorghum plants have more secondary feeding roots and a smaller leaf area per plant than corn of comparable seasonal requirement. This combination of an efficient moisture-absorbing system with a reduced evaporation surface also accounts in part for their greater ability to withstand drought. The ability of sorghum plants to remain dormant during period of severe drought and resume growth when rain falls make them dependable sources of grain and forage in areas which are normally too dry for corn (Martin and Stephens, 1955).

Sorghum may be grown on almost any type of soil, but deep, fertile, well drained, sandy loam soils are most desirable. Heavy clay soils produce good crop in seasons of normal rainfall, but severe drought injury may result during dry season. Sorghum is fairly tolerant to alkali soil (Wesley, 1955). If soils are not highly susceptible to erosion, perparation of the land (plowing and furrowing) should be started as early as conditions permit. A warm firm, moist seedbed is essential. Seeds should be 1 to 2 inches deep. It is advisable to plant twice as much seeds per acre as would be required to give the desired number of plants in the row. When sorghum is drilled for hay, 25-40 pounds of seeds per acre are required for best results. Rate of seeding for most varieties of forage sorghum in the western part of Oklahoma is 3.4 to 5.7 kg of seeds per hectare. In the eastern section, the recommended rate of seeding is 5.7 to 9.1 kg per hectare. In western Oklahoma, the highest grain yield obtained by spacing grain sorghum plants 6 to 8 inches apart and 4 to 6 inches for forage (Wesley, 1955).

Grain sorghum yield is strongly influenced by soil water content at planting and the use of that water during the growing season (Paul, 1991). Jones and Hauser (1975) showed that sorghum grain yield in the southern Great Plains at Bushland, TX, U.S.A increased (1.7 Kg/m^{-3} water) when additional available water was stored in the soil at planting. Parashar (1979) found that severe stress during heading reduced grain yield significantly. Musick and Dusek (1971) concluded that moisture stress during the vegetative growth stage had less effect on yield than stress from heading through grainfill. However, the former stress period did reduce head size. Lewis et al., (1974) found that grain yield was reduced by 17% when moisture stress was imposed from late vegetative growth to booting, and 34% reduction when the stress occurred between booting and flowering. Shipley and Regier (1975) found that stress during booting stage resulted in only partially extruded heads and the portion that failed to emerge produced no grain. Shipley *et al.*, (1971) showed that daily water use peaks was at heading. This supports the argument that heading is the most critical growth stage for irrigation. In contrast, Stewart et al., (1975) concluded that grain sorghum was three times as sensitive to evapotranspiration (ET) deficits at the vegetative stage than at either pollination or grainfill. They also found that when limited irrigation was practiced, maximum water use efficiency, yield, and profit were obtained when ET was met through booting, allowing dificits thereafter.

Water absorption at greater soil depths is desirable for minimizing the injurious effect of plant water stress. Root penetration of sorghum was controlled by the seasonal wetting front and soil pH (Zaongo et at., 1994). Deep movement of the wetting front offered the potential for deeper root penetration. Sorghum roots tended to be deeper with favorable soil moisture and chemical environment. They found that effective rooting depth was defined at the top soil depth in which 80% of the roots are located.

Sorghum do best in the southern half of the United States, where the temperature during growth is about 26.6°C, and they grow very little at temperatures below 15.5°C. Sorghum is not so exacting in their moisture requirements as in their temperature relation. All sorghums are sensitive to cold soils and grow slowly unitl the soil becomes thoroughly warm. No advantage is gained, therefore, by planting too early (Martin and Stephens, 1955).

Experiments in USA showed that the highest yields of sorghum silage were obtained when complete fertilizer (6-10-4 or 6-20-4) was used (Martin and Stephens, 1955). Phosphorus was most effective in increasing yields followed by nitrogen, and potassium.

Sorghum should be fairly mature before being cutting for forage, the reasons for this are: 1) The feed is more palatable, 2) The plant contains less prussic acid, 3) The fodder does not sour in the shock so easily, and 4) The silage made from mature sorghum contains less acid and does not spoil when properly ensiled (Martin and Stephens,1955). When sorghum is grown for grain, harvesting should not be started until the heads are well matured. This is indicated by color, hardness, and moisture content of the grain. In western Oklahoma, it is common practice to leave the grain in the field unitl after frost. The moisture content of sorghum grain should not exceed 12 percent when it is placed in storage. Forage sorghum is usually harvested when the grain is in the hard or late dough stage, and before loss of lower leaves (Wesley, 1955).

2.3 Soil Crust Phenomena.

Soil surface sealing is a common feature of cultivated soils in many regions of the world. Surface crusts are thin (<2mm) and are characterized by greater density, high shear strength, finer pores, and lower saturated hydraulic conductivity than the underlying soil (McIntyre, 1958a; Onofiok and Singer,1984; Bradford et al., 1987). Soil crusts have a prominent effect on many soil properties. For example, reduction of water infiltration and increase in runoff, slowing of the soil-atmosphere gas exchange, and interference with seedling emergence (Baver et al., 1972; Bradford et al., 1987).

2.4 Crust Formation

We have to distinguish between two types of crust according to their mechanisms of formation: i) Structural crust is caused by the impact action of the water drops. This mechanism produces a thin skin seal at the soil surface (McIntyre, 1958a&b). ii) Depositional crust is caused by a physicochemical dispersion of the soil clays allowing them to migrate into the soil with infiltrating water, and clog the pores immediately beneath the surface (the "washed-in" zone) (McIntyre, 1958 a&b).

The thickness of skin seal and the washed-in zone are 0.1 mm and 2 mm, respectively. The permeabiltiy of the underlying cultivated soil was higher than that of the washed-in layer by 200 times and about 2000 times higher than of skin seal (McIntyre, 1958 a&b).

Al- Muwaqqar soils texture is generally silty caly. Soil surface structure is poor, prone to crusting. Crust thickness is about 0.5-2 cm (Jean, et al., 1995).

2.5 Phosphorus (P) Fertilization

Dryland soils are usually poor in organic matter (OM), which in turn, weakens soil structure and reduces their chemical fertility. Arid soils usually contain from 0.1% to 1% OM, while semi-arid soils contain from 1% to 3% (Hagin and Tucker, 1982). As a consequence, **P** behavior in dryland soils is dominated by inorganic soil compounds. As most dryland soils are calcareous, solubility relationship dictated by high pH and $CaCO_3$ combine to produce low levels of soluble P in soils. As a result, most dryland soils which have not been fertilized are P-deficient.

Utilization of applied P by plants growing in soil is usually less than 10% because P changes to less available forms, and to the low diffusion coefficients of P in soils so that most of the available P is not close enough to the roots (Schenk and Barber, 1979). Phosphorus uptake by plants is affected by the rate of P supply from the soil and the P absorption characteristics of the roots (Barber, 1978). Plant P absorption characteristics are: affected by root surface area exposed to P; and the relation between P influx and P concentration in solution at this root surface (Anghinoni and Barber, 1980).

Phosphorus is not lost by leaching. Hanson and MacGregor (1966) indicated that P accumulated in the surface 7.6 cm of soil planted to alfalfa that received annual P broadcast and moved very little below 7.6 cm.

2.6 Factors Associated with Crop Phosphorus Responses

P fertilizer recommendation must be adjusted to consider the many field conditions that affect fertilizer use; some may reduce the need for P, while others may accentuate the fertilizer requirement. These factors are:

2.6.1 Water - Use Efficiency

Under the semi-arid climate, water is obviously the most limiting factor that affects plant growth. Water use efficiency (WUE), is a useful guide to imporving crop management (Cooper et al., 1988). It expresses production in terms of yield per hectare per millimeter of available water. It is defined as:

$$\text{WUE} = \frac{TE}{(1 + Es / T)} \text{ kg/ha/mm}$$

where:

TE: Average seasonal crop transpiration efficiency (kg/ha^{-1} mm^{-1})

Es: Water loss as evaporation from the cropped soil (mm).

T: Average seasonal transpiration (mm).

They indicated that the interaction between fertilizer and water use is largely due to more rapid growth and canopy development during early growth stage. Solar energy is intercepted by the crop, and less reaches the soil surface. As a result, soil evaporation (Es) is reduced and crop transpiration (T) increases. Fertilizer reduces the Es/T rates and thus leads to greater WUE.

Applied **P** to dificient soils accelerated crop development and hastened maturity by up to 2 weeks (Shepherd et al., 1987). Fertilizer **P** enhanced root growth, therefore, increased crop's ability to extract moisture stored in the soil during the spring and early summer (Cooper et al., 1987).

2.6.2 Rainfall and Soil Moisture

Several theories have been advanced to explain the positive effects of **P** on improving crop growth in low-rainfall conditions. With the improved stimulation of root growth by **P** fertilization, the effective availability of nutrient is increased, due to increasing the soil volume accessible for water and nutrients by the rooting system. Since the crop takes up most of its **P** from solution, absorption of **P** by roots is greatly reduced under condition of low soil water availability (Olsen et al., 1961). Application increases the concentration of soluble **P** in the moisture film around the soil particles, thus compensating for the small number of contact point between soil particles and root surfaces (Matar, 1977).

2.6.3 Available Soil Phosphorus Levels

A calibrated soil test (the process of determining the crop-soil test relationship) value for a prticular nutrient will indicate the degree of availability of that nutrient and the amount of the fertilizer nutrient to be applied. The $NaHCO_3$-extractable **P** (Olsen- P) test is extensively used in the arid and semi-arid regions as a reliable and most practicale test for available **P** determination in calcareous soils. Experiments in field calibration indicated that the levels of Olsen-P in soil that optimize wheat and barley yields ranged between 5 to 10 ppm, depending upon climate and soil conditions. Higher critical Olsen-P levels occurred under low- rainfall conditions (Harmsen et al., 1983; Krentos and Orphanos, 1979; Matar, 1976 b). Little or no responses of wheat to **P** application were observed in wet years, even if the available **P** was around 4 to 5 ppm. However in dry years, the critical level could exceed 8 to 9 ppm (Soltanpour et al., 1988 ; Matar, 1976 b; Krentos and Orphanos, 1979). Furthermore, the critical level was well related to soil properties. A more detailed study at **ICARDA** (1983-1988) concluded that a level of 10 ppm soil **P** at sowing of winter cereals or a legume crop should secure an optimum **P** availability over the range of various soils and climatic conditions of the Mediterranean regions.

2.6.4 Residual Phosphorus

Phosphorus added to soil is subject to chemical transformation into less available forms (Barrow, 1974), with rate varying with soil types and properties and several environmental conditions, e.g., temperature and moisture. A yearly application of 18 kg P/ha on a vertisol, with wheat/ lentil rotation, raised Olsen-**P** from 2 to 8 ppm within 4 years (Matar, 1976a). Similarly, yearly application of 27 kg P/ha for 5 years to a typic Calciorthid with different barley rotation increased **P** from 2.5 to 12 ppm (Jones and Matar, 1990).

2.6.5 Phosphate Application Methods

Broadcasting P fertilizer and incorporating it with soil at sowing is the common practice used by most farmers. However, evidence has accumulated that **P** banded, or drilled with the seeds, is more efficient than broadcasting.

Jackobs et al. (1970) indicated that **P** incorporated into the seedbed was used more efficiently than **P** broadcast on an existing alfalfa stand. Soltanpour et al. (1988) found when wheat grown on 4.5 ppm Olsen-P, the grain responded to broadcasting, followed by disking, but response to banded **P** continued further. In dry site in Syria (280 mm), banded **P** produced relatively higher grain yield of durum wheat compared with broadcast (Matar and Brown, 1989). Placement of alfalfa seeds over band of **P** gave maximum seedling stimulation from fertilizer (Tesar et al., 1954). Alfalfa seedlings had to be directly over banded or 1 inch away from **P** banded 1.5 inches deep in order to obtain 60% or more of their **P** from the fertilizer in two months, while seedlings 3 inches away from banded **P** received less than 3% of their **P** from the fertilizer during the same period. Plants directly over fertilizer band produced 52 and 66%. more top growth than when plants were 1 or 2 inches away from the fertilizer, respectively. Abdel Monem *et al.* (1990) found that banding increased **P** uptake but not yield.

Two mechanisms explain the advantageous effect of banding on **P** fertilizer effeciency under field conditions, i) Banding reduces soil- fertilizer contact, which in turn decreases **P** immobilization and ii). Increases the root-P fertilizer contact, thus P concentration resulting in greater **P** uptake.

2.7 Legumes and Forages Responses to P Fertilizer

Low level of native soil **P** in west Asia is accentuated by a higher **P** requirement by forage legumes. Economic responses to applied **P** have been observed for lentil and fababean (FAO,1970; Matar, 1976a; Badawy, 1976; Sharar et al., 1976). The average responses to **P** were much greater and more consistent in a dry year than in a wet one. Similar results obtained on lentil and chickpea (Haddad, 1986a; 1986b). Osman et al.(1990) indicated that surface **P** application to natural pastures or marginal grazing areas without tillage increased plant population and yield of native legume species. Application of 25 kg P/ha increased legume seed yield from 21 to 99 kg/ha. Walworh et al., (1986) noted that **P** applied broadcast 3yr after alfalfa establishment increased yields on low initial **P** treatment. Nelson et al., (1986) demonstrated declines in alfalfa plant density 3 to 5 yr after establishment due to P deficiency.

2.8 Root Characteristics as Related to P Uptake

Difference between species according to their ability to utilize soil **P** were partially explained through variation of root morphology (Atkinson, 1973; Barley, 1970). Root morphology may be described by root radius, root length, root surface/shoot weight ratio, and root hair density.

Chemical effects of roots on the soil environment can be involved in **P** uptake processes from soils (Barber, 1978; McLachlan, 1976).

Factors such as rate of growth, fineness of roots and root hairs were considered the most effective variables influencing **P** uptake (Silberbush and Barber, 1983). Mean root radius differed significantly between 5 corn genotypes at high **P** supply and was generally smaller at low **P**. This behavior of plants to reduce root radius instead of root length under shortage of assimilates during **P** deficiency seemed to be mechanism for increasing the root surface per unit root weight (Schenk and Barber, 1979). They also found that root length was not affected by P supply.

Anghinoni and Barber (1980) indicated that restricting the amount of roots supplied with P reduced root weight but had no effect on root length. They also found when less than 50% of the roots were supplied with P, root growth rate in the P solution culture was 25% greater than in the minus P solution. The reduction of root growth in the minus P solution may be due to lack of sufficient P to combine with the photosynthate to provide additional root growth. Haynes and Ludecke (1981) found no relationship between P uptake and total root mass in pot-grown plants of lotus and white clover. In contrast, P uptake in P-deficient soils was related to root fineness (Fohse et al., 1991) or density (Aboulross and Nielsen, 1979). Under field conditions, P uptake was related to root length (Steffens, 1984). A strong positive association (r= 0.846) was observed between root length and P uptake in high-P soils, but not at the low- P soil site (r= 0.253) (Takashi and Noriharu, 1996). Phosphorus uptake was closely related to root length in maize (Jung and Barber, 1974). Matt and Ronald (1993) indicated that alfalfa root mass planted under O-P soil was concentrated in the upper 20 cm of soil, whereas under adequate to high P, more root mass was distributed throughout the upper 40 to 50 cm. Nearly 80% of the root mass in O-P was in the upper 20 cm of soil, whereas this same proportion of root mass was distributed in the upper 40-50 cm of soil received 59 kg Pha^{-1}.

2.9 Furrow Irrigation System

Increasing infiltration rate, and therefore, increasing soil water storage can be obtained by using furrow irrigation system. Lack of silt action and less crusting on the sides of the furrows were important factors in allowing this increase in water intake. Furrow diking increases detention storage capacity which reduces surface runoff and provides enough time for water intake.

Previous investigation at Al-Muwaqqar Station on the same site indicated that soil water storage associated with furrows increased significantly by 62% and 200% as compared to basin and control surface treatments, respectively.(Akasheh, 1996) Branson et al. (1966) indicated that soil moisture storage had increased by applying contour furrowing at 3-5 foot intervals, and the prennnial grasses increased to about 500 lb/acre. In desert grassland of southern Arizona furrowing effect produced 2.5 times more grass than adjacent untreated range area (Brown and Evasion, 1952). Wider ridges (beds) between furrows could be an advantage providing they can be wetted up satisfactorily.

3. MATERIALS AND METHODS

3.1 Study Site

The experiment was carried out during 1996/1997 at the University of Jordan Research Station at Muwaqqar. The site is located 50 Km southeast of Amman (Latitude of 36 0′5′, N, longitude of 31 4′9″E and altitude of 760 m asl). The climate is typical Mediterranean arid with wet winter and dry summer. Rainfall varies from 80 to 200 mm with annual mean of 150 mm falling mostly during January and February. Mean maximum and minimum temperatures during January (coldest month) are 13 and 3°C, respectively, while for August (warmest month), they are 33 and 17°C, respectively. Mean relative humidity for January and August is 70 and 45%, respectively. Mean sunshine is 9 hours day^{-1}, while mean annual incident solar radiation is 550 langleys day^{-1} (Taimeh, 1989).

The soils are highly calcareous with carbonate varying from 20 to 70% with low organic matter. They have a strong platy structure and a high silt content. A surface crust is usually formed after rainfall or irrigation which results in very low infiltration rates.

3.2 Land Preparation

Two sites were selected, the first (location1) with deep soil profile (1.7 m), and the second (location 2) with shallower depth (0.5-0.7m). The total area for each location was 5.2 dunums. The maximum slope at the first location was about 1.5%, while at the second location the slope was less than 1%. The soil at the two study locations are fine silty, mixed, thermic, Typic calciorthid (Taimeh, 1989). Generally, the area at both locations is characterized by little vegetative cover, soil surface of high silt content, strong surface crust, low organic matter and weak aggregate stability.

Land preparation started at the beginning of August, 1996. Each replicate consisted of large plot (strip about 77m long and 21m wide) was prepared in each location for both crops. The plots were plowed (30cm) by chisel. Furrows (trenches) about 30 cm deep and 40cm wide on one meter interval were initiated at the soil surface of the plot (Fig.1). The furrows direction was perpendicular to the slope direction. Stilling basin/ channel system (Fig.2) was initiated to feed water into the long contour furrows by pumping the water directly from the dam to the basin to each soil profile. Each plot was subdivided into 3 subplots to apply three rates of **P** fertilization.

3.3 Planting and Fertilization

One half of each strip was planted with alfalfa and the other half was planted with sorghum. Alfalfa (WL605) seeds were planted at a rate of 40 kg/ha. Planting date was from 20 to 29 of March 1997. Seeds were broadcast on the ridges and covered with soil at about 1.5 -2.5cm depth.

Sorghum (AZRA3) seeds were planted on the two edges of the ridges at about 300,000 seeds/ha (3seeds/pit). Seeds were soaked with water for 24 hours before planting. Planting date was from 1 to 10 of April 1997. Spacing between rows was 0.6 m and 0.2 m between plants.

Triple superphosphate (TSP) (45% P_2O_5) was applied to alfalfa and sorghum at planting date. Phosphorus application rates were 0 (P_1), 22.5 (P_2) and 45 (P_3) kg P_2O_5 /ha.

At alfalfa site, TSP was broadcasted on the surface of the ridges and was incorporated with alfalfa seeds with soil. At sorghum site, TSP was applied in pits 2.5 cm directly below the seeds.

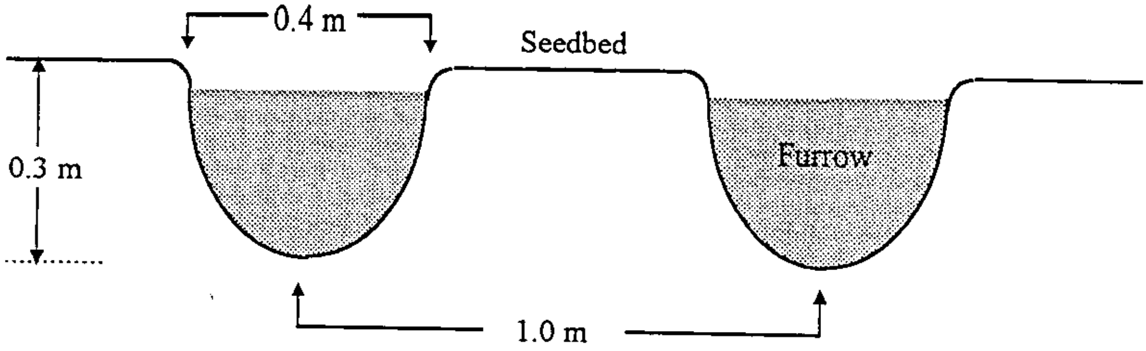

Figure 1. Deep furrow layout.

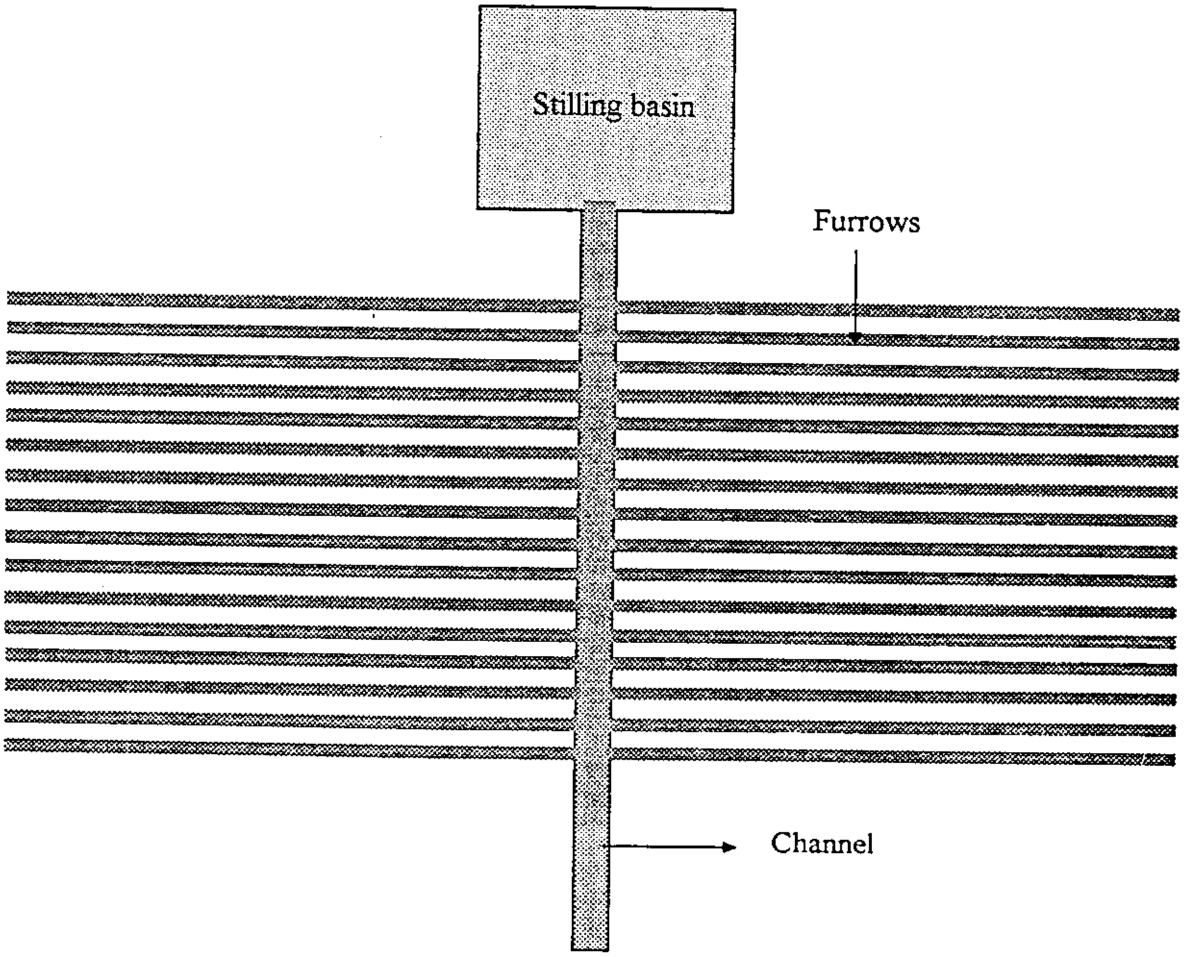

Figure 2. Stilling basin / Channel system.

3.4 Irrigation

Total seasonal rainfall amount was 154.8 mm which fell during the period from 18th November to 24th March 96/97. Rainfall distribution is shown in Appendix A Table 1. Water was pumped to location 1 before planting during the period from 25th February to 14th of March 97. The amount of water applied was 520 m^3. Another 520 m^3 was pumped to Location 1 during the period from first to 15th April.

Water was pumped to location 2 during the period from 10 to 20th April. The amount of water applied was 390 m^3. After planting alfalfa in both locations water was added by handsprinkler at a rate of 21L/ridge to keep seedbeds wet.

Because of low germination and emergence, both locations were irrigated by sprinkler from 7th to 28th May. The amount of water applied by sprinkler was 12 mm for each location. At the end of water application, the soil at location 1 reached field capacity to the depths between 90-105 cm. The soil profile at location 2 reached to the field capacity to the full depth (70cm).

3.5 Weed Control

Weeds were controlled manually as needed.

3.6 Measurements

3.6.1 Soil test measurements

Some physical and chemical properties of soil were measured such as:

Soil texture using pipette method (Gee and Banter, 1986). Bulk density of the soil using the core method (Blake and Hartage, 1986). Soil water content at field capacity was measured gravimetrically in the field.

Permanent wilting points was determined at 15 bars (1.5 MPa) using ceramic plate pressure apparatus (Peters, 1965). Available **P** before planting and after harvesting was determined using Olsen procedure (Extraction with 0.5 *M* $NaHCO_3$ at pH 8.5) (Olsen and Dean, 1965).Soil electrical conductivity was measured using paste extracts method (Bower and Wilcox, 1965).

3.6.2 Soil moisture measurements

For the soil moisture measurements, an access tube was installed in each plot to a depth of 1.35 m and 0.7 m at location (1) and (2), respectively. The access tubes were installed gently in the soil by removing the soil with a small-diameter auger inserted inside the access tube during installation. Soil moisture was monitored during the growing season beginning on 4th June 1996, at 10 day intervals and ended on 12th of September at 15cm increments starting from the second layer (15-30 cm). Soil water content of the first 0-0.15m depth was determined gravimetrically.

3.6.3 Evapotranspiration (ET) Measurement

Evapotranspiration (ET) was calculated by soil moisture depletion from all soil layers in the root zone (i to n) using the following equation.

$$\text{Evapotranspiration (ET)} = \sum_{i}^{n} (P_{v2} - P_{v1}) \times D/100$$

where

ET = Evapotranspiration mm/ period.

P_{v1} = Volumetric water content (%) at present reading.

P_{v2} = Volumetric water content (%) at previous reading.

D = Soil depth (mm).

Seasonal crop ET was calculated by summing up all ET/period values.

3.6.4 Crop Measurements

At harvest, the following measurements were done for each plot;

a) Alfalfa yield: One the 12th of September all the area was harvested at 40% flowering stage, alfalfa cut at 10 cm height. Then samples were taken to determine alfalfa water content. The samples were dried at (70 °C for 24 hr) and yield were reported on a dry weight basis.

b) Sorghum stover yield: On the 12th of September all the area was harvested, sorghum for stover yield was cut 1 to 2 cm above the soil surface and weight, then samples were taken to determine stover water content. The samples were dried at 60 °C, and yield was reported on dry weight basis. Panicle dry matter other than grain was included in the stover yield.

c) Sorghum grain yield for each plot at location (1) only: For grain yield stems were cut 1 to 2 cm below the panicles. The panicles were oven-dried at 60 °C, then threshed to determine grain yield which was reported on a dry weight basis.

D) Plant coverage percentage and seedling emergence percentage for each plot and for each crop at each location was estimated by eye.

3.6.5 Root distribution

To estimate root distribution for alfalfa and sorghum, one plant from each plot was chosen for each treatment at the two locations. Deep profiles were made beside each selected plant to the needed depth to reach the roots. Soil cores, 50 mm inside diameter and 100 mm deep were used to collect roots at 0.15 m increments. Roots were collected by washing the soil from each depth increment by water through a fine sieve (1mm pores diameter). Then the total root length (tap and laterals roots) was measured and root length density was expressed as cm (root length)/ cm^3 of soil.

3.7 Experimental Design and Statistical Analysis

For each crop at each location randomized complete block design (RCBD) was adopted in this experiment.

Three rates of (P) fertilizer treatments were used with three replications. The experimental layout is shown in Fig (3).

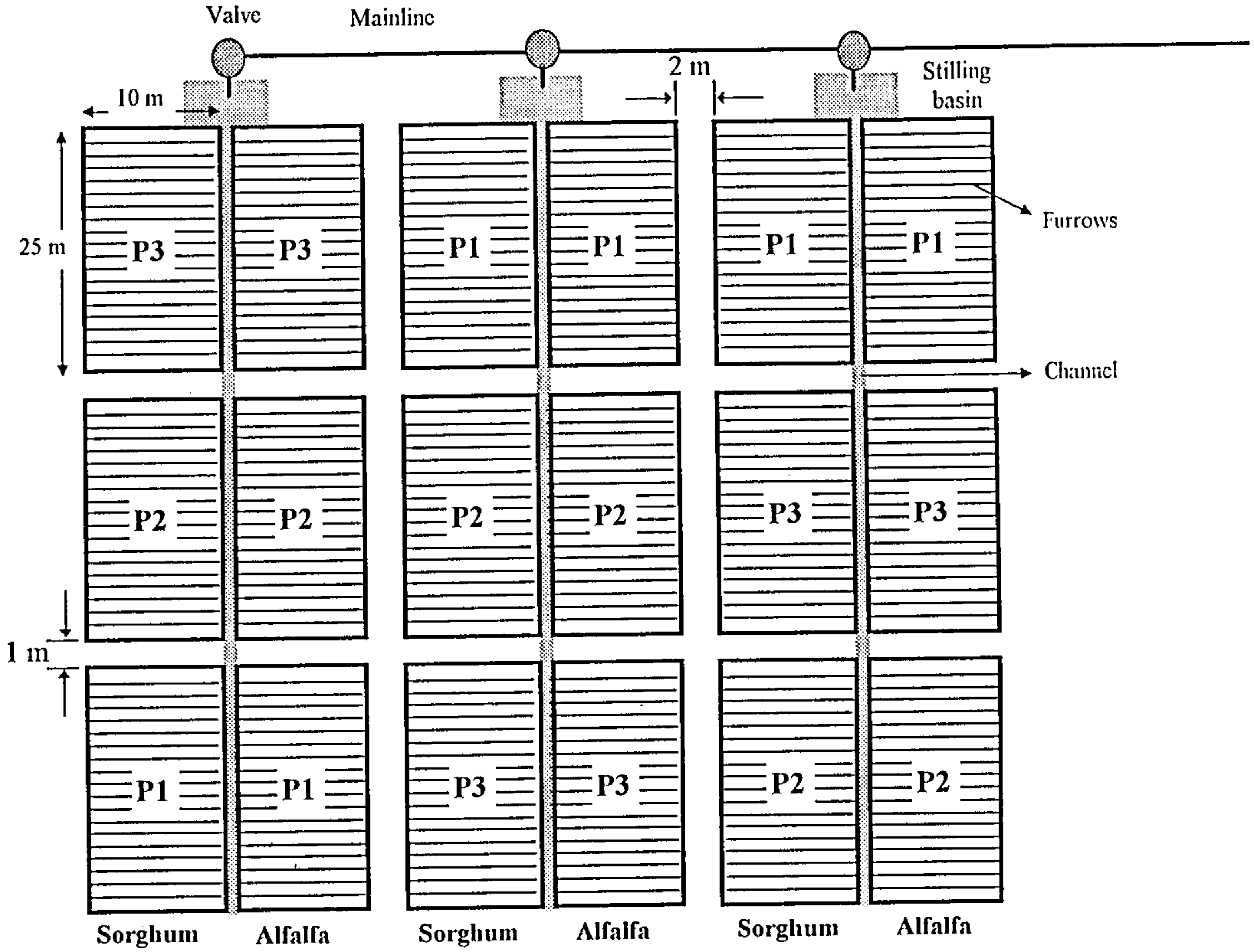

Figure 3. Experiment layout

4. RESULTS AND DISCUSSION

4.1 Soil Properties

Table 1 shows some physical and chemical soil properties at locations 1 and 2. Table 2 shows particle size distribution and texture classes of the soil profile at locations 1 and 2.

Neutron probe calibration curves and regression equations for each layer at both locations are shown in Figures 4 and 5.

4.2 Rainfall and Water Applied

Seasonal precipitation during 96/97 was about normal. Total amount of rainfall was 154.8 mm. Rainfall distribution is shown in Appendix A Table 1. The amount of rainfall and total water applied to both locations (1 and 2) before and after planting is shown in Table 3. Available water storage capacity at location 1 was 183.4 mm to 1.35 m depth, and at location 2 was 93.3 mm to 0.7 m depth. Available soil water is between -0.033 and -1.5 MPa matric potentials. After water applications, the soil at location 1 reached to field capacity to depths between 90 to 105 cm. All the soil profile at location 2 reached the field capacity to 70 cm depth. The hardpan at 90 to 105 cm depth at location 1 restricted water penetration to deeper depth.

4.3 Evapotranspiration Measurements

Total alfafa and sorghum evapotranspiration (ET) under the different phosphorus treatments at both locations 1 and 2 are shown in Table 4.

4.3.1 Alfalfa Evapotranspiration at Location 1

Table 5 shows alfalfa ET and ET for each layer in the root-zone as affected by P treatments. Statistical analysis showed no significant effect of

Table 1: Some physical and chemical soil properties for location 1 and 2.

Location	Soil depth (cm)	Bulk density (g/cm^3)	Field capacity (Pv %)	Wilting Point (Pv%)	ECe dS/m	Phosphorus available (ppm)
1	0-15	1.30	27.00	15.5	1.50	20
	15-30	1.29	30.25	16.4	1.50	20
	30-45	1.32	30.76	16.5	1.55	
	45-60	1.36	30.65	17.2	1.60	
	60-75	1.32	34.09	17.4	1.55	
	75-90	1.44	33.38	18.3	1.60	
	90-105	1.36	30.77	17.4	1.65	
	105-120	1.41	30.92	17.1	1.65	
	120-135	1.30	26.86	16.6	1.60	
2	0-15	1.27	28.14	16.6	1.50	13
	15-30	1.22	28.26	16.8	1.55	13
	30-45	1.34	34.49	18.7	1.60	
	45-60	1.29	34.67	18.5	1.65	
	60-70	1.27	30.26	19.4	1.65	

Table 2: Particle size distribution and texture classes of the soil profile at locations 1 and 2.

Location	Soil Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture Class
1	0-15	31.2	45.1	23.7	Clay Loam
	15-30	33.8	42.1	24.1	Clay Loam
	30-45	36.2	40.8	23.0	Clay Loam
	45-60	34.5	43.1	22.4	Clay Loam
	60-75	34.8	42.4	22.8	Clay Loam
	75-90	32.7	43.2	24.1	Clay Loam
	90-105	32.4	41.0	26.6	Clay Loam
	105-120	32.4	38.9	28.7	Clay Loam
	120-135	33.4	37.7	29.1	Clay Loam
2	0-15	35.8	39.9	24.3	Clay Loam
	15-30	37.4	40.8	21.8	Clay Loam
	30-45	41.9	37.9	20.2	Clay
	45-60	42.5	37.5	20.0	Clay
	60-70	43.4	36.6	20.0	Clay

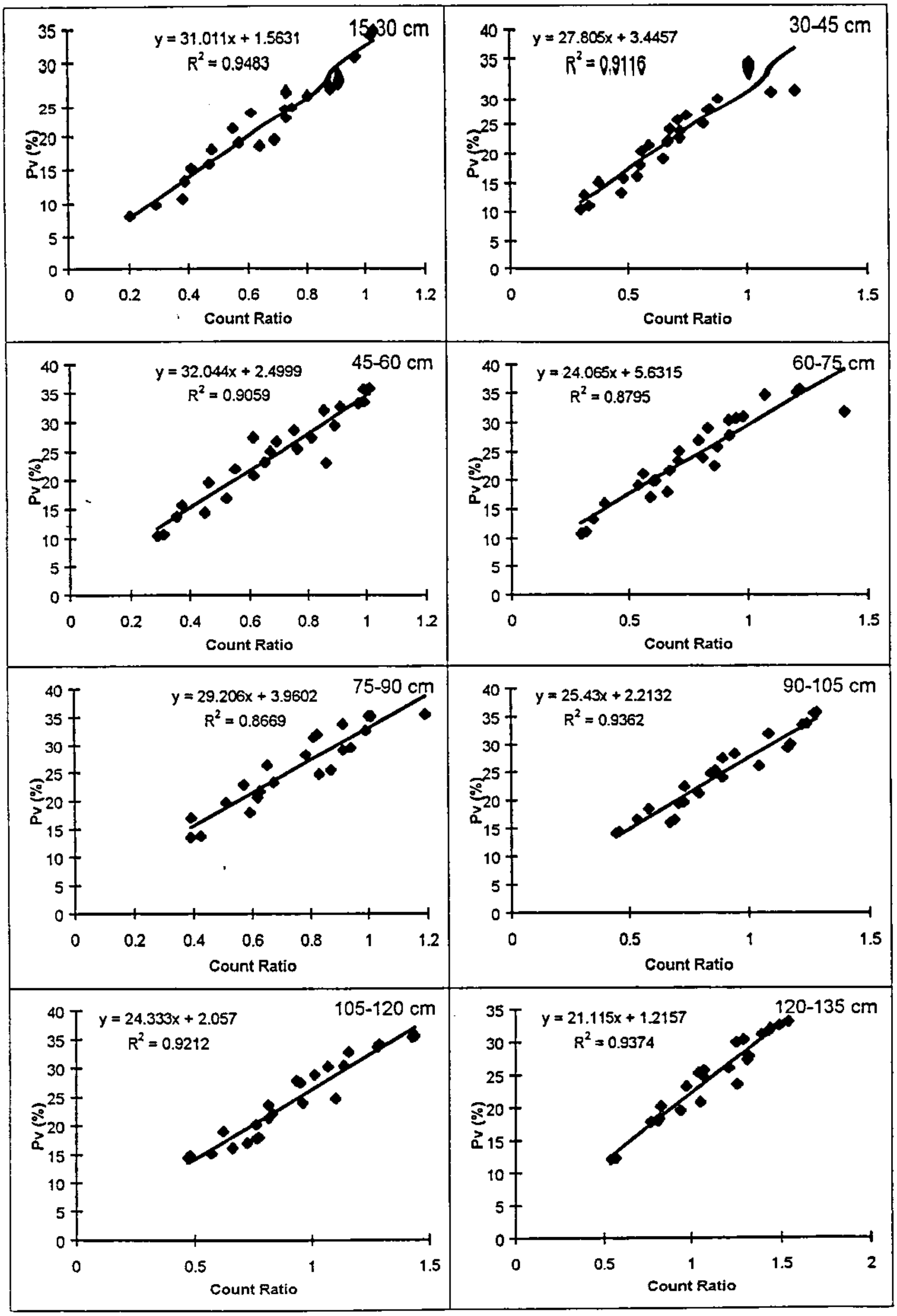

Fig. 4: Neutron probe calibration curves for each layer at location 1.

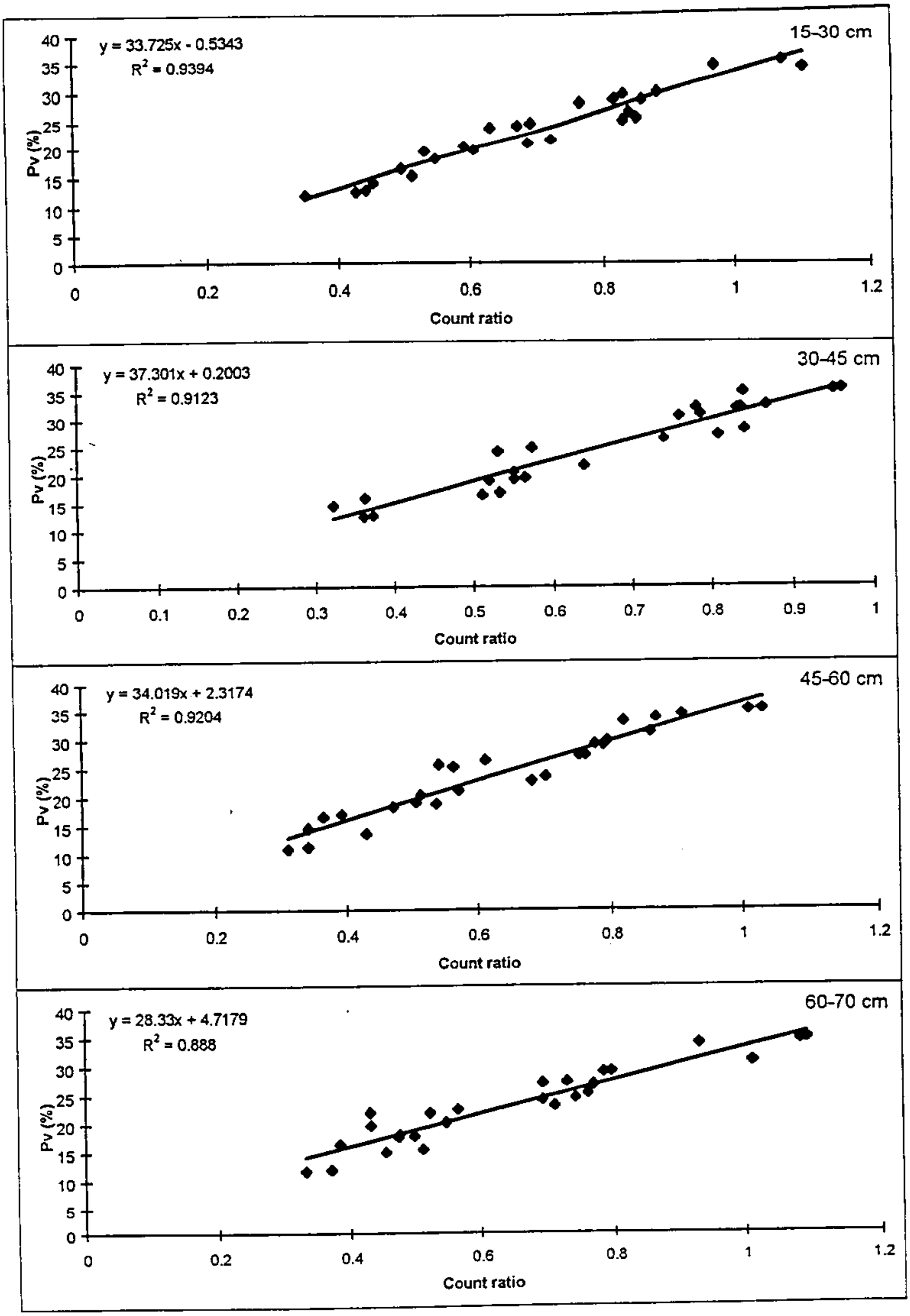

Fig. 5: Neutron probe calibration curves for each layer at location 2.

the different phosphorus treatments on alfalfa ET. This might be because of the soil reached to field capacity to 90 to 105 cm depth only, and alfalfa roots penetrated the soil under all **P** treatments to the depth where water reached (due to relatively high initial available **P** in the soil) and used this water.

Table (3): Amount of rainfall and total water applied (mm) each location 1 and 2 before and after planting.

	Location 1		Location 2	
	Alfalfa	**Sorghum**	**Alfalfa**	**Sorghum**
Irrigation before planting	100.8	100.8	-	-
Irrigation after planting	114.6	112.8	89.4	87.6
Rainfall	154.8	154.8	154.8	154.8
Total water applied	**370.2**	**368.4**	**244.2**	**242.4**

Table (4): Seasonal evapotranspiration (mm) for alfalfa and sorghum at both locations 1 and 2 as affected by P treatments.

Phosphorus treatment	Location 1		Location 2	
	Alfalfa	**Sorghum**	**Alfalfa**	**Sorghum**
P1	153.025 a*	126.470 b	084.340 c	102.790 b
P2	146.397 a	129.465 ab	109.820 b	123.100 a
P3	145.850 a	140.540 a	133.680 a	123.760 a

*** Values within the same column with different symbols show significant differences between values using Duncan's Multiple Range Test at 0.05 probability level.**

Under all P treatments more than 59% of the soil water extraction was from the 0-0.45 m depth. Layer one (0-15 cm) had the highest percentage of soil water extraction (22.5%) followed by layer two (20.2%) and layer three (17.3%), with rather low changes at greater depths. Changes in soil water content during the growing season for the entire profile is shown in Figure 6. Soil water was depleted even at soil water potential below -1.5 MPa especially at the top 45 cm (where more roots at that depth were found) as shown in Table 6. Little amount of available water remained in soil on the 12th of September in layers 4 (45-60cm), 5 (60-75cm), 6 (75-90cm) and 7(90-105 cm) as shown in Table 6.

4.3.2 Sorghum Evapotranspiration at Location 1

Table 7 shows total sorghum ET and ET for each layer in the root zone as affected by P treatments. Average sorghum ET were 126.47, 129.46 and 140.54 mm under **P1, P2, P3** respectively. Statistical analysis showed no significant differences in ET between **P1** and **P2** treatments and between **P2** and **P3** treatments, while ET under **P3** treatment was significantly higher than ET under **P1** treatment. This is because of the greatest total root length and root penetration under **P3** treatment compared to **P1** treatment due to high **P** application.

Table (5): Seasonal evapotranspiration (mm) for alfalfa as affected by P treatments at location 1.

Phosphorus treatment	Soil layers	Average
P1	L_1 (0-15cm)	33.275
	L_2 (15-30 cm)	30.660
	L_3 (30-45 cm)	26.505
	L_4 (45-60 cm)	16.710
	L_5 (60-75cm)	20.550
	L_6 (75-90 cm)	16.060
	L_7 (90-105 cm)	09.265
	Total	**153.025a***
P2	L_1 (0-15cm)	33.765
	L_2 (15-30 cm)	30.175
	L_3 (30-45 cm)	25.280
	L_4 (45-60 cm)	16.405
	L_5 (60-75cm)	21.795
	L_6 (75-90 cm)	18.970
	Total	**146.397a**
P3	L_1 (0-15cm)	33.445
	L_2 (15-30 cm)	29.180
	L_3 (30-45 cm)	25.200
	L_4 (45-60 cm)	16.150
	L_5 (60-75cm)	20.185
	L_6 (75-90 cm)	17.095
	L_7 (90-105 cm)	06.530
	Total	**145.215a**

* **Different symbols show significant differences between values using duncan's multiple range test at 0.05 probability level.**

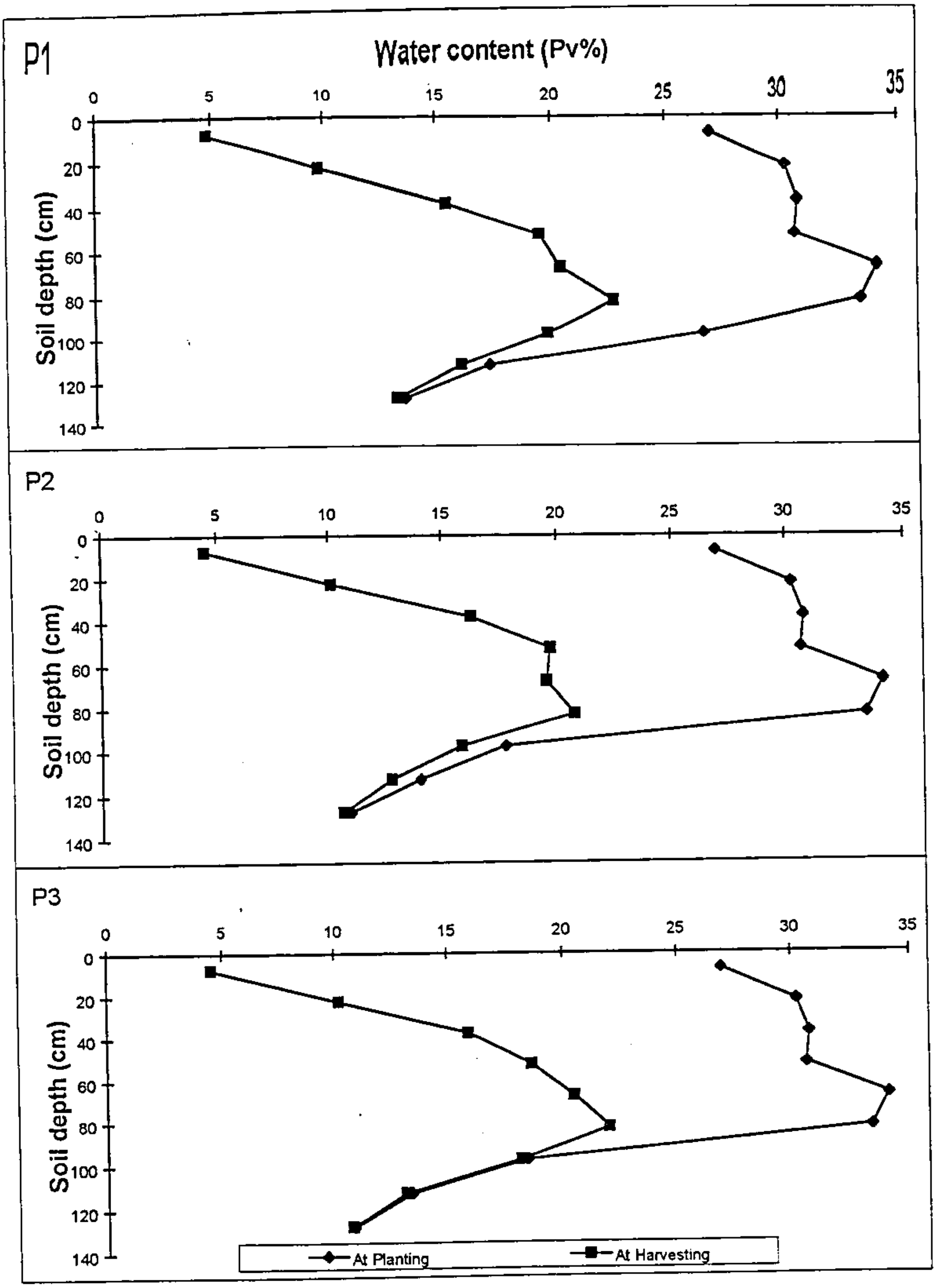

Figure 6. Soil water content (Pv%) at planting and harvesting for the entire soil profile planted with alfalfa as affected by P treatments at location 1.

Table (6) : Soil water content (Pv%) at PWP and soil water content (Pv%) on the 12th of September at 0-105 cm depth of soil planted with alfalfa as affected by diferent P levels at location one.

Phosphorus treatment	Depth (cm)	PWP* (Pv%)	Average soil water content (Pv%) on 12th september
P1	0 - 15	15.5	04.80
	15 - 30	16.4	09.80
	30 - 45	16.5	15.46
	45-60	17.2	19.51
	60-75	17.4	20.39
	75-90	18.3	22.67
	90-105	17.4	19.83
P2	0 -15	15.5	04.49
	15 - 30	16.4	10.13
	30 - 45	16.5	16.22
	45-60	17.2	19.71
	60-75	17.4	19.56
	75-90	18.3	20.73
	90-105	17.4	15.85
P3	0 - 15	15.5	04.54
	15 - 30	16.4	10.22
	30 - 45	16.5	15.93
	45-60	17.2	18.68
	60-75	17.4	20.48
	75-90	18.3	21.99
	90-105	17.4	18.13

* PWP : Permanent wilting point..

Table (7): Seasonal evapotranspiration (mm) for sorghum as affected by P treatments at location 1.

Phosphorus treatment	Soil layers	Average
P1	L_1 (0-15cm)	33.940
	L_2 (15-30 cm)	30.255
	L_3 (30-45 cm)	25.720
	L_4 (45-60 cm)	16.545
	L_5 (60-75cm)	20.010
	Total	**126.470 b***
P2	L_1 (0-15cm)	34.460
	L_2 (15-30 cm)	30.310
	L_3 (30-45 cm)	24.890
	L_4 (45-60 cm)	17.135
	L_5 (60-75cm)	22.670
	Total	**129.465 ab**
P3	L_1 (0-15cm)	34.150
	L_2 (15-30 cm)	29.580
	L_3 (30-45 cm)	24.510
	L_4 (45-60 cm)	14.305
	L_5 (60-75cm)	20.157
	L_6 (75-90 cm)	17.970
	Total	**140.540 a**

*** Different symbols show significant differences between values using duncan's multiple range test at 0.05 probability level.**

Under all **P** treatments more than 67% of the soil water extraction was from the 0 - 0.45 m depth. Layer one (0-15 cm) had the highest percentage of soil water extraction (26%) followed by layer two (22.8%) and layer three (19%), with rather low changes at greater depths. This result agree with those found by Paul (1991). Changes in soil water content during the growing season for the entire profile are shown in Figure 7. Soil water depleted even at soil water potential below -1.5 MPa especially at the top 30 cm where more roots at that depth were found as shown in Table 8. Some of available water remained in soil on 12 th September in layers 4(45-60 cm), 5 (75-90 cm), 6 (75-90 cm) and 7 (90-105 cm) depth as shown in Table 8.

4.3.3 Alfalfa Evapotranspiration at Location 2

Table 9 shows total alfalfa ET and ET for each layer in the root-zone as affected by **P** treatments. Average alfalfa ET were 84.34, 109.82 and 133.68 mm under **P1, P2** and **P3** respectively. Statistical analysis showed significant differences in ET among **P** treatments. The highest ET was under **P3** followed by **P2** and **P1** treatments. This is because of the greatest total root length and root penetration under **P3** treatment and the lowest total root length and root penetration under **P1** treatment due to high and low **P** applications under **P3** and **P1** respectively.

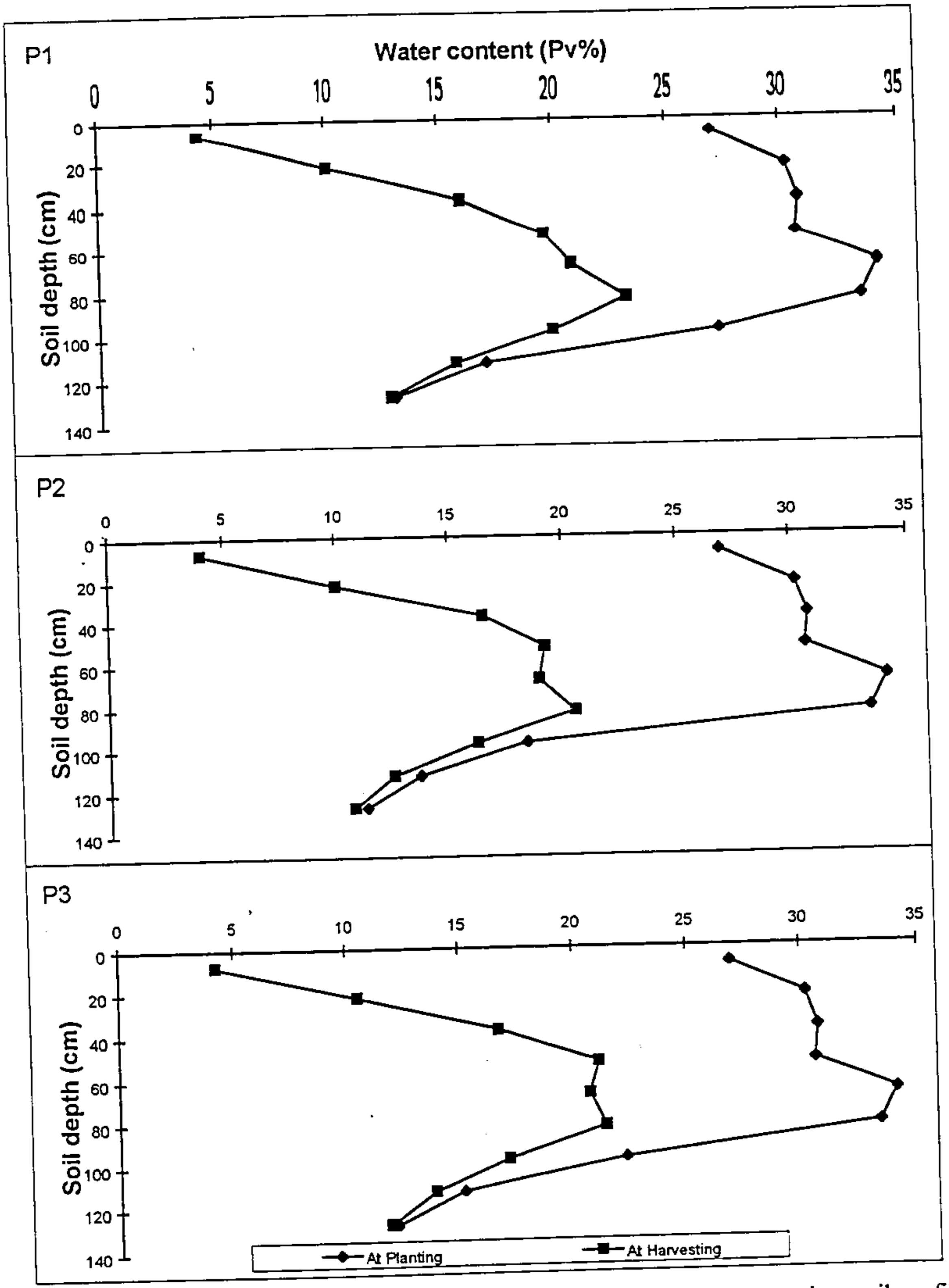

Figure 7. Soil water content (Pv%) at planting and harvesting for the entirer soil profile planted with sorghum as affected by P treatments at location 1.

Table (8): Soil water content at PWP (Pv%) and soil water content (Pv%) on the 12th september at 0-150 cm depth of soil planted with sorghum as affected by P levels at location 1.

Phosphorus treatment	Depth (cm)	PWP* (Pv%)	Average soil water content (Pv%) on 12th september
P1	0-15	15.5	04.37
	15-30	16.4	10.08
	45-60	17.2	19.62
	60-75	17.4	20.75
	75-90	18.3	23.14
	90-105	17.4	19.93
P2	0-15	15.5	04.03
	15-30	16.4	10.04
	45-60	17.2	19.23
	60-75	17.4	18.98
	75-90	18.3	20.50
	90-105	17.4	16.25
P3	0-15	15.5	04.23
	15-30	16.4	10.53
	45-60	17.2	21.11
	60-75	17.4	20.71
	75-90	18.3	21.40
	90-105	17.4	17.19

* PWP: Permantet wilting point

Table (9): Seasonal evapotranspiration (mm) for alfalfa as affected by different P treatments at location 2.

Phosphorus treatment	Soil layers	Average
P1	L_1 (0-15cm)	33.935
	L_2 (15-30 cm)	26.915
	L_3 (30-45 cm)	23.490
	Total	**84.340 c***
P2	L_1 (0-15cm)	33.640
	L_2 (15-30 cm)	26.240
	L_3 (30-45 cm)	25.745
	L_4 (45-60 cm)	24.195
	Total	**109.820 b**
P3	L_1 (0-15cm)	34.295
	L_2 (15-30 cm)	26.660
	L_3 (30-45 cm)	26.790
	L_4 (45-60 cm)	25.175
	L_5 (60-70cm)	20.760
	Total	**133.680 a**

* Different symbols show significant differences between values using Duncan's Multiple Range test at 0.05 probability level.

Under all **P** treatments more than 45% of the soil water extraction was from the 0-0.30 m depth. Layer one (0-15cm) had the highest percentage of soil water extraction (32%) followed by layer two (25%). Changes in soil water content during the growing season for the entire profile is shown in Figure 8. Soil water was depleted even at soil water potential below -1.5 MPa especially at the top 45 cm due to the high evaporation from that depth as shown in Table 10. In all **P** treatments. Negligible amounts of available water remained in soil on 12th September in layers 4 (45-60 cm) and 5 (60-75 cm) depth. There were significant differences between alfalfa ET at the two locations under all **P** treatments. Alfalfa at location 1 had ET significantly higher than alfalfa at location 2. Average alfalfa ET values at location one were 153, 146.4 and 145.8 mm under **P1**, **P2** and **P3** respectively, while average alfalfa ET values at location 2 were 84.34, 109.8 and 133.7 mm under **P1**, **P2,** and **P3,** respectively. This was because alfalfa at location 1 had higher: average seedling emergence percentage (as shown in Appendix C), plant coverage percentage, total root length and roots penetration than alfalfa at location 2. Also amount of water stored in soil profile at planting at location 1 was higher than at location 2.

4.3.4 Sorghum Evapotranspiration at Location 2

Table 11 shows the amount of sorghum ET and sorghum ET for each layer in the root zone as affected by different **P** treatments. Average sorghum ET were 102.8, 123.1 and 123.8 mm under **P1**, **P2** and **P3** respectively. Statistical analysis showed no significant differences in ET between **P2** and **P3** treatments while ET under **P2** and **P3** treatments was significantly higher than ET under **P1** treatment. This was because root penetration under **P2** and **P3** treatment reached the end of soil profile (0.7 m) which enabled it to absorp water from deep soil while root penetration under **P1** treatment reached only to 0.45-0.6 m depth. Also total root length

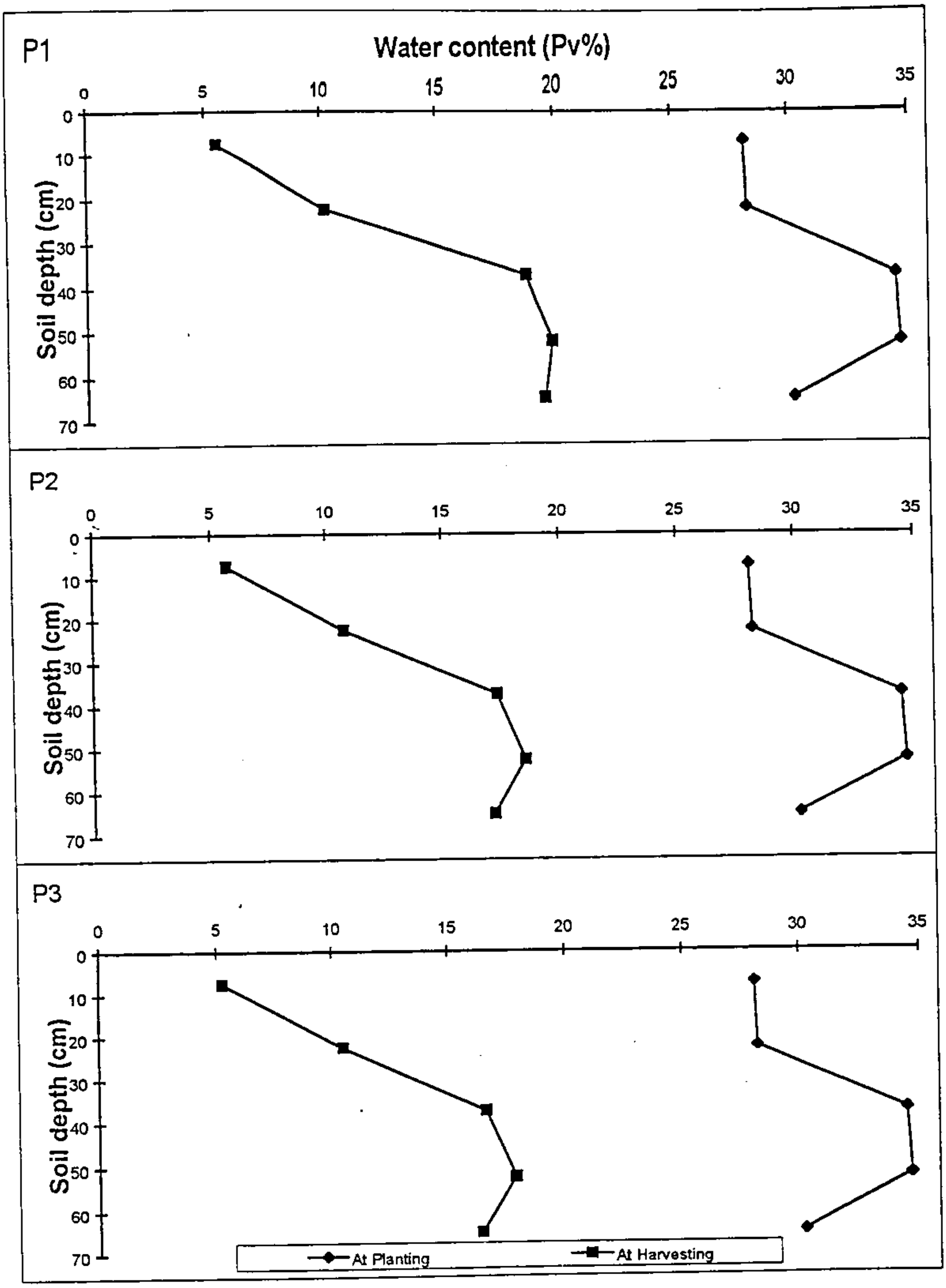

Figure 8. Soil water content (Pv%) at planting and harvesting for the entire soil profile planted with alfalfa as affected by P treatments at location 2.

Table (10): Soil water content at PWP (Pv%) and soil water content (Pv%) on the 12 th of September at the top 45 cm of soil planted with alfalfa as affected by P treatments at location2.

Phosphorus treatment	Depth (cm)	PWP* (Pv%)	Average soil water content (Pv%) on 12th september at the top 45 cm
P1	0-15	16.6	05.52
	15-30	16.8	10.32
	30-45	18.7	18.83
P2	0-15	16.6	05.71
	15-30	16.8	10.77
	30-45	18.7	17.33
P3	0-15	16.6	05.22
	15-30	16.8	10.49
	30-45	18.7	16.63

* PWP : Permanent wilting point

Table (11): Seasonal evapotranspiration (mm) for sorghum as affected by P treatments at location 2.

Phosphorus treatment	Soil layers	Average
P1	L_1 (0-15cm)	33.955
	L_2 (15-30 cm)	24.365
	L_3 (30-45 cm)	23.015
	L_4 (45-60 cm)	21.455
	Total	**102.790 b***
P2	L_1 (0-15cm)	34.720
	L_2 (15-30 cm)	24.990
	L_3 (30-45 cm)	23.805
	L_4 (45-60 cm)	22.845
	L_5 (60-70cm)	16.740
	Total	**123.100 a**
P3	L_1 (0-15cm)	34.415
	L_2 (15-30 cm)	24.490
	L_3 (30-45 cm)	25.090
	L_4 (45-60 cm)	22.455
	L_5 (60-70cm)	17.310
	Total	**123.760 a**

* Different symbols show significant differences between values using Duncan's multiple range test at 0.05 probability level.

under **P2** and **P3** was greater than under **P1** treatment due to **P** fertilizer application. Under all **P** treatments more than 68% of the soil water extraction was from the 0-0.45 m depth. Layer one (0-15 cm) had the highest percentage of soil water extraction (29.6%) followed by layer two (21.3%) and layer three (20.6%). Changes in soil water content during the growing season for the entire profile is shown in Figure 9. Soil water was depleted even at soil water potential below -1.5MPa (Table 12) especially at the top 30 cm depth where more roots at that depth were found. In all **P** treatments negligible amounts of available water remained in soil on 12th September in layers 4 (45-60 cm) and 5 (60-70 cm) depth. There were significant differences between sorghum ET values at the two locations under all **P** treatments. Average sorghum ET values at location one were 126.5, 129.5 and 140.5 mm under **P1**, **P2** and **P3** respectively, while average sorghum ET values at location two were 102.8, 123.1 and 123.8 mm under **P1**, **P2** and **P3** respectively. This is because sorghum at location one had: higher average seedling emergence percentage (as shown in Appendix C), plant coverage percentage, total root length and root penetration than sorghum at location 2. Also amount of water stored in soil profile at planting at location one was higher than at location two.

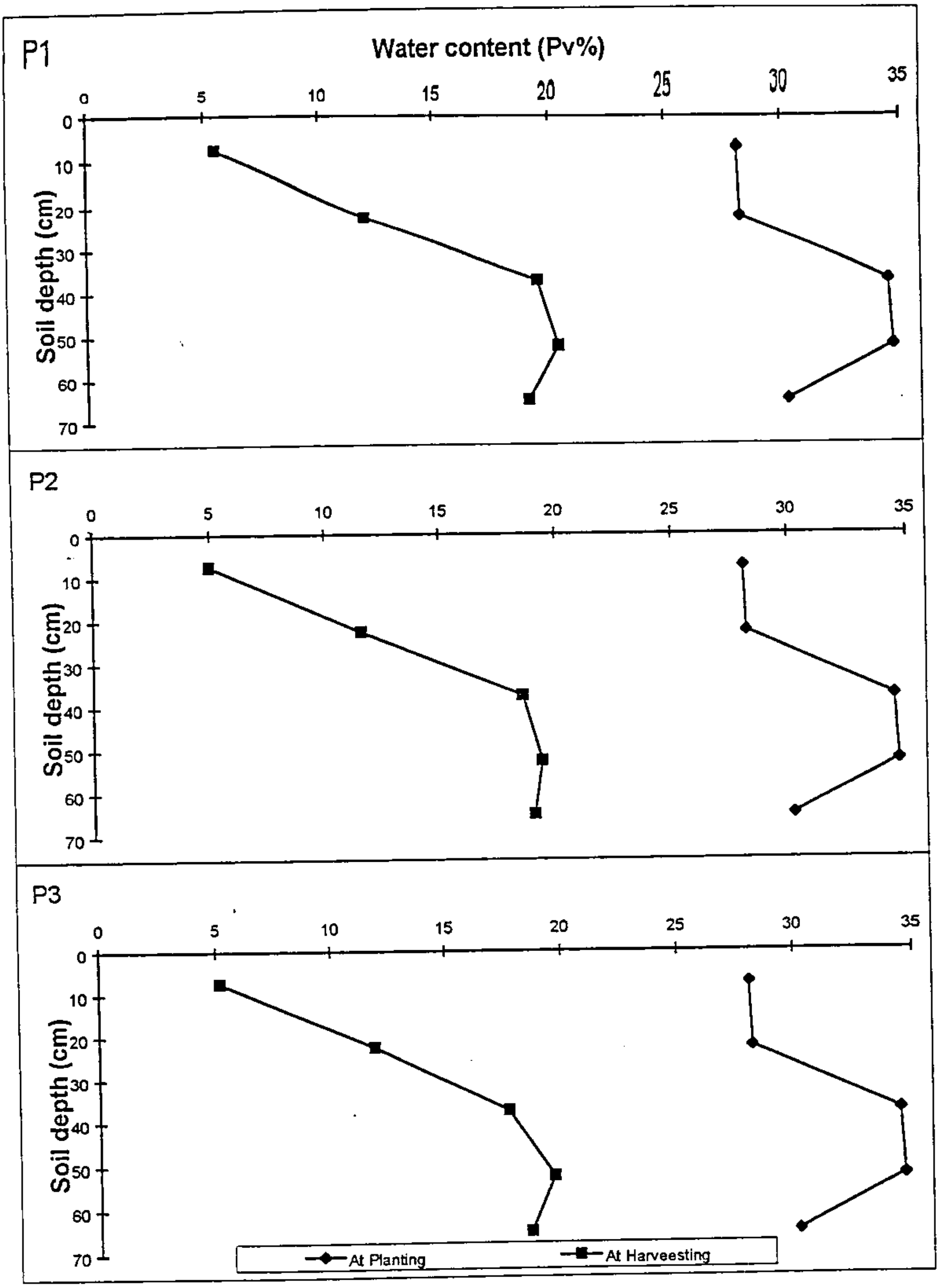

Figure 9. Soil water content (Pv%) at planting and harvesting for the entire soil profile planted with sorghum as affected by P treatments at location 2.

Table (12) :Soil water content at PWP and Soil water content on the 12th of September at the top 30cm of soil planted with sorghum as affected by P levels at location two.

Phosphorus treatment	Depth (cm)	PWP* (Pv%)	Average soil water content (Pv%) on 12th september at the top 30 cm
P1	0-15	16.6	05.50
	15-30	16.8	12.02
P2	0-15	16.6	04.99
	15-30	16.8	11.60
P3	0-15	16.6	05.20
	15-30	16.8	11.93

* PWP : permanent wilting point

4.4 Root Distribution

4.4.1 Alfalfa Root Distribution at Location 1

Table 13 shows alfalfa root distribution as affectecd by different **P** levels at location 1. The greatest total alfalfa root length was found under the highest phosphorus level **P3** (9.02 cm/cm^3 soil). Alfalfa under **P1** treatment had greater total root length (8.75 cm/cm^3 soil) than alfalfa under **P2** treatment (4.84 cm/cm^3 soil). This could be attributed to : i) plant available phosphorus at the top 30 cm of the soil before planting was 20 ppm which might be adequate for alfalfa, ii) high water storage under **P1** treatment compared to **P2** treatment because soil reached field capacity to 105 cm depth under **P1** while it reached field capacity to only 90 cm depth under **P2** due to existence of hardpan layer at this depth (Abdul-jabbar *et al.* (1982) found that greatest alfalfa root length distribution under the high moisture levels) and iii) plant variability (only one plant was sampled for rooting in each treatment). Alfalfa roots penetrated the soil to depth where water reached because of high initial **P** in the soil. Alfalfa roots concentrated at soil depth from 0-30 cm for all **P** levels (59-83%) and the greatest differences in alfalfa root distribution among **P** levels were observed in the upper 30 cm. Alfalfa roots were found at least at 90 cm soil depth for all **P** levels. Root length density values for alfalfa at various soil depths and for different **P** levels are shown in Figure 10. Seventy five to ninty two percent of alfalfa roots were found at the top 45 cm of the soil profile under different **P** levels. The percentage of total alfalfa roots at each depth averaged over the three ranges of **P** levels are shown in Figure 11, and curvilinear curves were fitted to the relationship regardless of **P** level.

4.4.2 Sorghum Root Distribution at Location 1

Table 14 shows sorghum root distribution as affected by **P** levels at location 1. The greatest total sorghum root length was found under the highest phosphorus level **P3** (10.96 cm/cm^3 soil), followed by **P2** treatment (7.69 cm/cm^3 soil) and **P1** treatment (7.40 cm/cm^3 soil). This is

Table 13: Alfalfa root distribution (cm/cm^3 soil) as affected by different P levels at location 1.

Depth cm	Phosphorus treatments		
	P1	P2	P3
00-15	3.83	1.89	4.07
15-30	3.43	0.97	2.97
30-45	0.78	0.77	0.88
45-60	0.21	0.62	0.51
60-75	0.13	0.54	0.30
75-90	0.21	0.05	0.16
90-105	0.16	0	0.13

Table 14: Sorghum root distribution (cm/cm^3 soil) as affected by different P levels at location 1.

Depth cm	Phosphorus treatments		
	P1	P2	P3
00-15	2.93	3.46	7.17
15-30	2.13	1.60	1.04
30-45	1.15	1.26	2.08
45-60	1.18	0.82	0.54
60-75	0.01	0.55	0.09
75-90	0	0	0.04

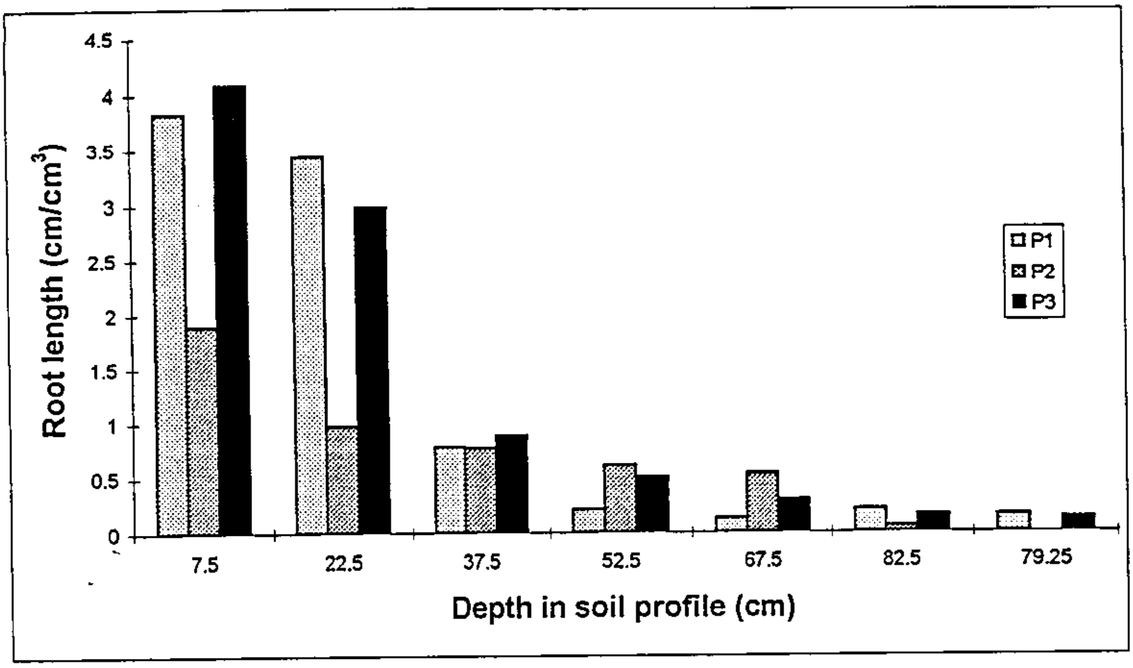

Fig. 10: Effect of P level on the average root length distribution of Alfalfa at different soil depths at location 1.

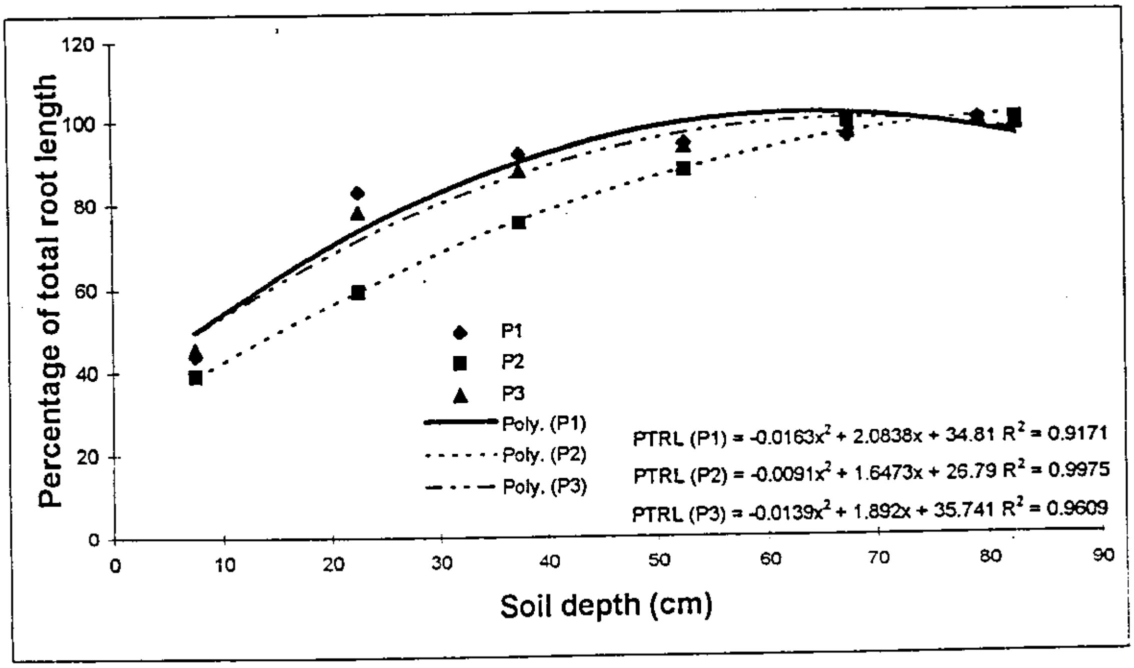

Fig. 11: The relationships between average percent of total root length distribution of Alfalfa for the P levels with different soil depths at location 1.

because of high available phosphorus under **P3** treatment. Sorghum roots concentrated at soil depth from 0-45 cm for all **P** levels (82-94%), and the greatest differences in sorghum root distribution among **P** levels were observed in the upper 30 cm. A greater rooting depth was found under **P3** (75-90 cm), sorghum roots were found at least at 75 cm soil depth for all **P** levels. Root length density values for sorghum at various soil depth and for different **P** levels are shown in Figure 12. Eighty two to ninety four percent of sorghum roots were found at the top 45 cm of soil profile under different **P** levels. The percentage of total sorghum roots at each depth averaged over three ranges of **P** levels are shown in Figure 13, and curvilinear curves were fitted to the relationship regardless of **P** level.

4.4.3 Alfalfa Root Distribution at location 2

Table 16 shows alfalfa root distribution as affected by **P** levels at location 2. The greatest total alfalfa root length was found under the highest **P** level (4.98 cm/cm^3 soil). **P2** treatment, had total root length (3.74 cm/cm^3 soil) greater than **P1** treatment (1.21 cm/cm^3 soil). This is because of high available phosphorus applied under **P3** treatment followed by **P2** treatment. Alfalfa roots concentrated at soil depth from 0-30 cm for all **P** levels (67-92%) and the greatest differences in alfalfa root distribution among **P** levels were observed in the upper 30 cm. A greater rooting depth was found under **P3** (end of soil profile). Alfalfa roots were found at least at 45 cm soil depth for all **P** levels. Root length density values for alfalfa at various soil depth and for different **P** levels are shown in Figure 14. Eighty eight to ninety two percent of roots were found in the top 30 cm of soil profile under different **P** levels. The percentage of total alfalfa roots at each depth averaged over three ranges of **P** levels are shown in Figure 15, and curvilinear curves were fitted to the relationship regardless of **P** level.

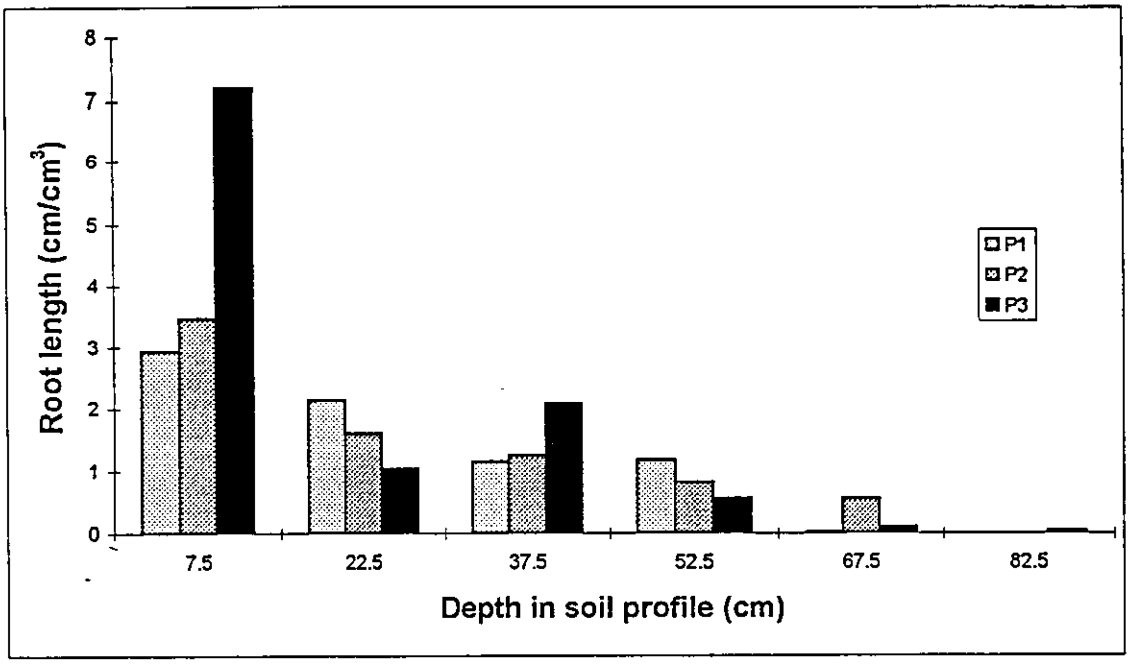

Fig. 12: **Effect of P level on the average root length distribution of Sorghum at different soil depths at location 1.**

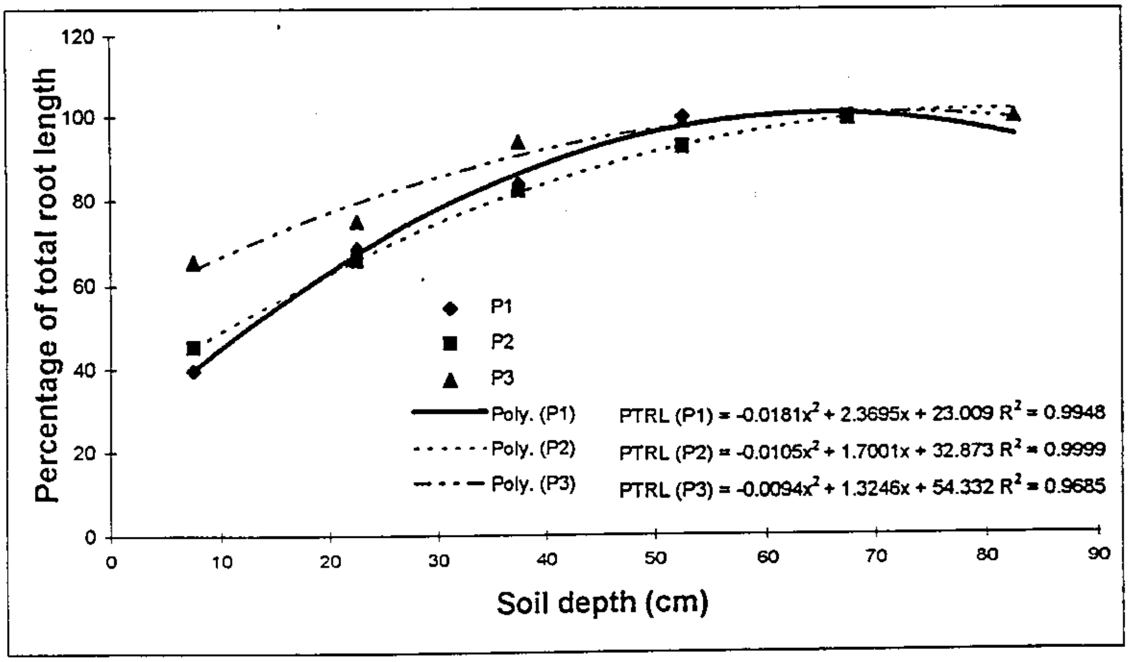

Fig. 13: The relationships between average percent of total root length distribution of Sorghum for the P levels with different soil depths at location 1.

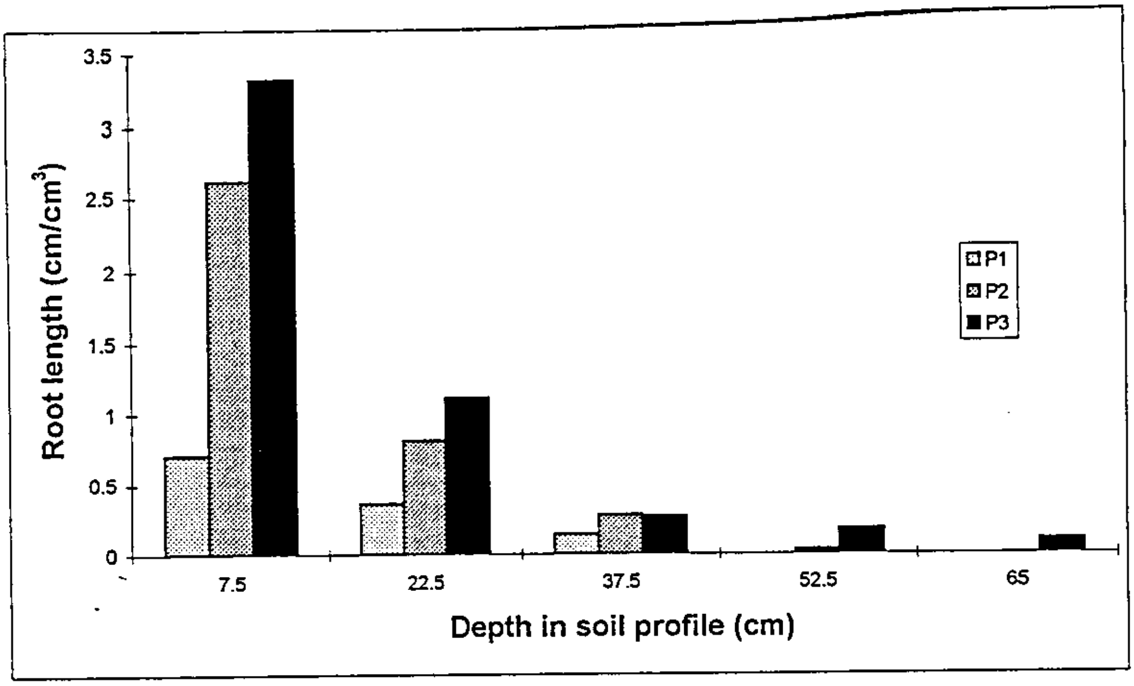

Fig. 14: Effect of P level on the average root length distribution of Alfalfa at different soil depths at location 2.

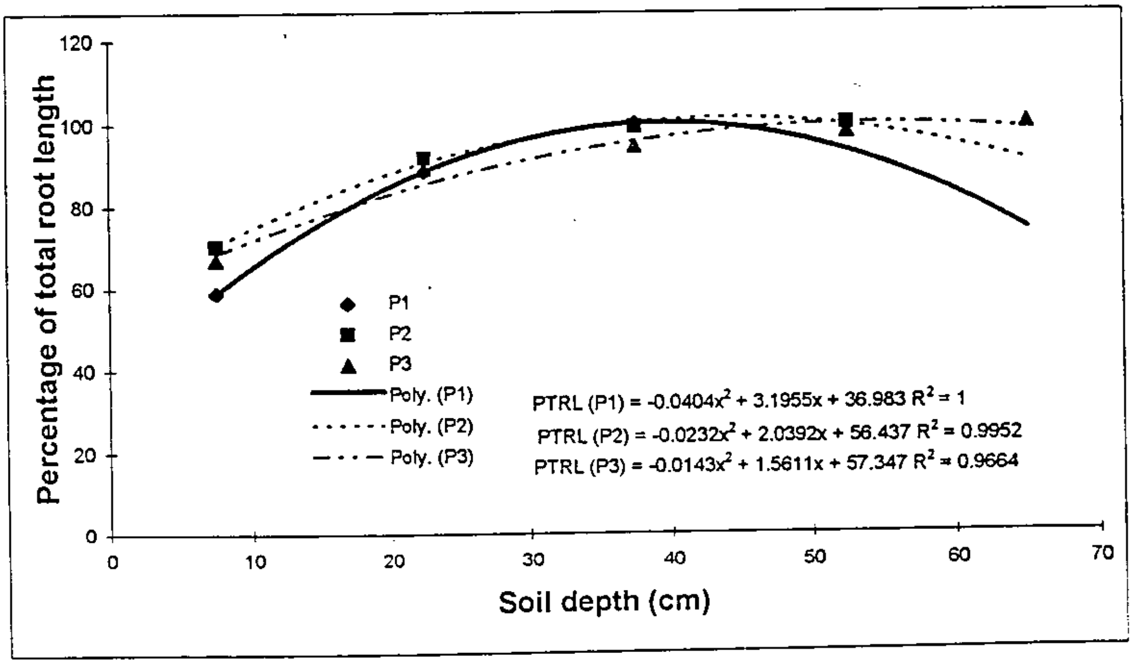

Fig. 15: The relationships between average percent of total root length distribution of Alfalfa for the P levels with different soil depths at location 2.

4.4.4 Sorghum Root Distribution at Location 2

Table 22 shows sorghum root distribution as affected by **P** level at location 2. The greatest total sorghum root length was found under the highest phosphorus level **P3** (8.41 cm/cm^3 soil) followed by **P2** (4.02 cm/cm^3 soil) and **P1** (3.30 cm/cm^3 soil). This is because of high phosphorus applied under **P3** treatment. Sorghum roots concentrated at soil depth from 0-45 cm for all **P** levels (89-95%) and greatest differences in sorghum root distribution among **P** levles wre observed in the upper 45 cm. Under **P3** and **P2** treatments sorghum roots reached the end of soil profile (70 cm) and under **P1** treatment, sorghum root was found at 45.60 cm soil depth. Root length density values for alfalfa at various soil depth and for different **P** levels are shown in Figure 16. Eighty nine to ninety five percent of sorghum roots were found in the top 45 cm of soil profile under different **P** level. The percentge of total sorghum roots at each depth averaged over three ranges of **P** levels are shown in Figure 17, and curvilinear curves were fitted to the relationship regardless of **P** levels.

4.5 Alfalfa and Sorghum Yields

4.5.1 Alfafa Yield at location 1

Table 17 shows the effect of the different **P** levels on alfalfa yield at location 1. Averages of alfalfa dry-matter yields were 3.579, 2.091 and 3.324 ton/ha under **P1, P2** and **P3** respectively. Statistical analysis showed no significant effect of different phosphorus treatments on alfalfa yield. The reason for the high alfalfa yield under **P1** treatment was the earlier alfalfa emergence and establishment by several weeks under R_1P_1 which enabled us to get two cuttings. Generally alfalfa yield was relatively low. Table 18 shows alfalfa dry-matter yield for the first harvest of the second season as

Table 15: **Alfalfa root distribution (cm/cm^3 soil) as affected by different P levels at location 2**

Depth cm	Phosphorus treatments		
	P1	P2	P3
00-15	0.71	2.62	3.32
15-30	0.36	0.81	1.11
30-45	0.14	0.28	0.27
45-60	0	0.03	0.18
60-70	0	0	0.10

Table 16: **Sorghum root distribution (cm/cm^3 soil) as affected by different P levels at location 2.**

Depth cm	Phosphorus treatments		
	P1	P2	P3
00-15	1.93	3.48	3.87
15-30	0.60	0.17	1.74
30-45	0.41	0.05	2.39
45-60	0.36	0.23	0.33
60-70	0	0.09	0.08

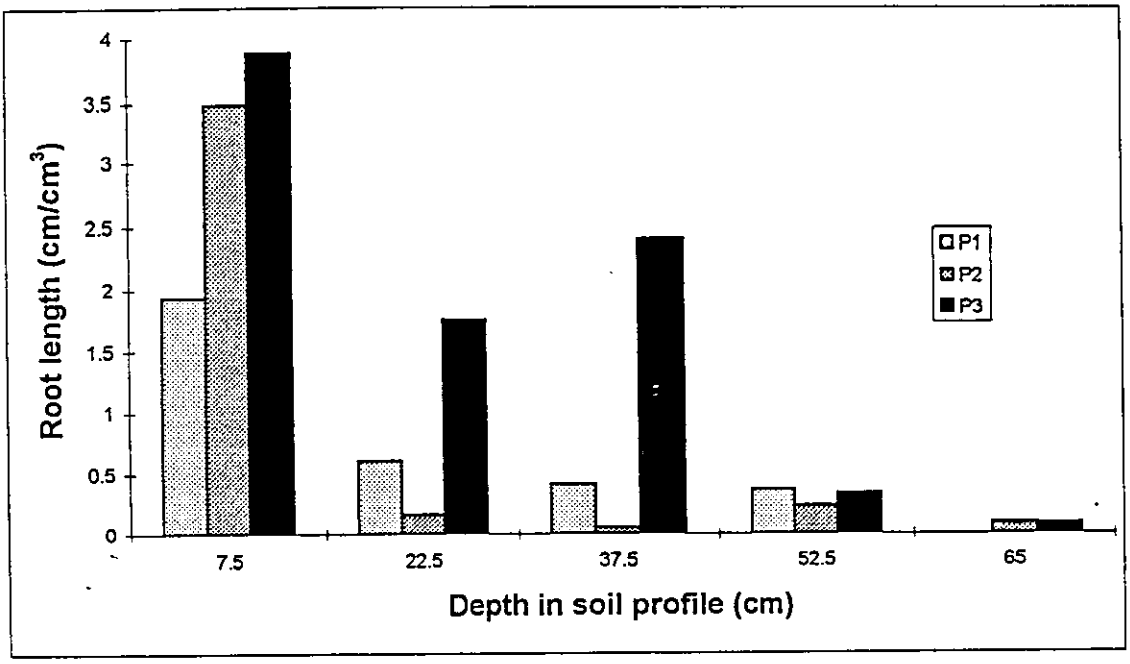

Fig. 16: Effect of P level on the average root length distribution of Sorghum at different soil depths at location 2.

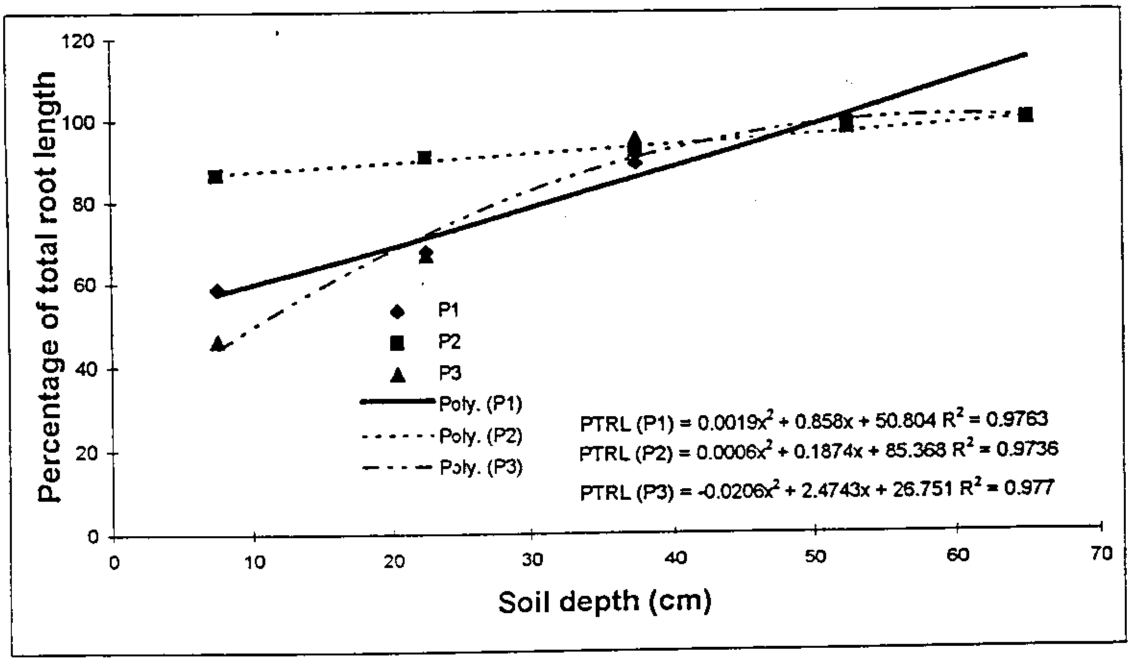

Fig. 17: The relationships between average percent of total root length distribution of Sorghum for the P levels with different soil depths at location 2.

Table 17: Alfalfa yield (ton/ha) as affected by different P levels at location 1.

Phosphorus treatment	Average
P1	3.579
P2	2.091
P3	3.324

Table 18: Alfalfa yield (ton/ha) for the first harvest of the second season as affected by different P levels at location 1.

Phosphorus treatment	Average
P1	1.521
P2	1.413
P3	1.148

Table 19: Sorghum stover yield (ton/ha) as affected by different P levels at location 1.

Phosphorus treatment	Average
P1	0.370 b *
P2	0.551 ab
P3	0.885 a

* Different symbols show significant differences between values using Duncan's multiple range test at 0.05 probability level.

for sorghum stover yield and sorghum grain yield. Sorghum grain yield was very low, this can be related to water stress at growth differentiation and booting stages. Hooker (1985) indicated that irrigation at growth differentiation stage resulted in a greater number of kernels per head and per unit area, whereas application at booting increased seed weight.

4.5.4 Alfalfa Yield at Location 2

Table 21 shows the effect of different phosphorus levels on alfalfa yield at location 2. No significant differences in alfalfa dry-matter yield between **P1** and **P2** treatments were found while **P3** treatment produced significantly higher alfalfa dry-matter yield than **P2** and **P1** treatments. Alfafa dry-matter yield increased under **P3** treatment (0.283 ton/ha) compared to **P2** (0.123 ton/ha) and **P1** (0.072 ton/ha) treatments by about 230% and 390%, respectively. This result is attributed to the deeper roots under **P3** treatments compared to **P2** and **P1** treatments, therefore, alfalfa could utilize water and nutrients at greater depth, and to the greatest total root length and ET under **P3** treatment. There were significant differences between alfalfa yield at the two locations under all **P** treatments. Alfalfa at location 1 had higher dry-matter yield than at location 2 for all **P** treatments. This is because alfalfa at location 1 had higher average seedling emergence percentage, plant coverage percentage, total root length, root penetration and seasonal ET than alfalfa at location 2.

4.5.5 Sorghum Stover Yield at Location 2

Table 22 shows sorghum stover yields as affected by different **P** levels at location 2. Averages of sorghum stover yield were 0.084, 0.146 and 0.161 ton/ha under **P1**, **P2** and **P3** respectively. Statistical analysis showed no significant effect of different phosphorus treatments on sorghum stover yield. High sorghum stover yield under **P3** treatment was attributed to the greatest total root length and ET under **P3** treatment. No sorghum grains

Table 20: Sorghum grain yield (ton/ha) as affected by different P levels at location 1

Phosphorus treatment	Average
P1	0.041 b *
P2	0.067 ab
P3	0.164 a

* Different symbols show significant differences between values using Duncan's multiple range test at 0.05 probability level.

Table 21: Alfalfa yield (ton/ha) as affected by different P levels at location 2.

Phosphorus treatment	Average
P1	0.072 b *
P2	0.123 b
P3	0.283 a

* Different symbols show significant differences between values using Duncan's multiple range test at 0.05 probability level.

Table 22: Sorghum stover yield(ton/ha) as affected by different P levels at location 2.

Phosphorus treatment	Average
P1	0.084
P2	0.146
P3	0.161

were produced due to water stress. There were significant differences between sorghum stover yield at the two locations under all **P** treatments. Sorghum at location 1 produced higher stover higher than at location 2 for all **P** treatments. This is because sorghum at location 1 had higher average seedling emergence percentage, plant coverage percentage, total root length and root penetration and seasonal ET than sorghum at location 2.

4.6 Alfalfa Coverage Percentage at Location 1

Tables 23 shows alfalfa coverage percentage for the first and second season respectively as affected by different **P** levels at location 1. The highest average alfalfa coverage percentage was under **P1** treatment (38.3%) followed by **P3** (23.7%) and **P2** (21%) treatments respectively (Table 23). This is because alfalfa under **P1** treatment had higher seedling emergence percentage than **P3** and **P2** treatments This might be because alfalfa under **P1** was planted first. In the second season alfalfa plant coverage percentage increased but not significantly under all **P** treatments. Table 23 shows the same trend for alfalfa coverage percentage where the highest coverage percentage was under **P1** treatment (62.67%) followed by **P3** (41.67%) and **P2** (38.33%) respectively This was because alfalfa under **P1** had higher seedling emergence percentage than under **P3** and **P2** treatments.

4.7 Total Phosphorus Uptake

Table 24 shows total phosphorus uptake by alfalfa in (kg/ha) as affected by different **P** levels at location 1. Average of total **P** uptake was 3.67, 3.73 and 4.80 kg/ha under **P1**, **P2** and **P3** respectively. There were no significant differences in total P uptake between **P1** and **P2** treatments while **P3** treatment was significantly higher total **P** uptake than **P1** and **P2** treatments. Total phosphorus uptake increased under **P3** treatment (4.80 kg/ha) compared to **P2** (3.73 kg/ha) and **P1** (3.67 kg/ha) treatments by about 129% and 131% respectively. This result is attributed to the higher **P** available and

Table 23: Alfalfa Plant Coverage Percentage for the first and second seasons as affected by different P levels at location 1.

Phosphorus treatment	First Season	Second Season
P1	38.30	62.67
P2	21.00	38.33
P3	23.70	41.67

total root length under **P3** treatment. This result agrees with those found by Takashi and Noriharu (1996) which idicated that **P** uptake by crops is strongly correlated with root length in soils when **P** availability is high.

4.8 Available Phosphorus After Harvesting

4.8.1 Available Phosphorus After Alfalfa Harvesting at Location 1

Table 25 shows **P** available at 30 cm soil depth after alfalfa harvesting as affected by different **P** treatments at location 1. Average **P** available values were 6 , 7.9 and 13.5 ppm under **P1, P2** and **P3** respectively. Statistical analysis showed no significant effect of the different **P** treatments on **P** available after harvesting. High **P** available under **P3** treatments was because of the high **P** applied under **P3** treatment. Under all **P** treatments **P** available after alfalfa harvesting was lower than initial **P** available in the soil before **P** fertilization.

4.8.2 Phosphorus Available After Sorghum Harvesting at Location 1.

Table 25 shows **P** available at 30cm soil depth after sorghum harvesting as affected by different **P** levels at location 1. Average **P** available values were 5.4, 22.7 and 66.7 ppm under **P1, P2** and **P3** respectively. There were no significant effect of the different phosphorus treatments on **P** available after sorghum harvesting because of high differences in **P** available among replicates within the same treatment due to spatial variability. High **P** available under **P3** treatment was because of the high **P** applied under **P3** treatment. Under **P3** and **P2** treatments, **P** available after sorghum harvesting was higher than initial **P** available in the soil before **P** fertilization, while under **P1** treatment **P** available was lower than initial **P** available.

Table 24: Total phosphorus uptake by alfalfa (kg/ ton dry-matter) as affected by different phosphorus level at location1.

Phosphorus Treatment	Average
P1	3.67 b
P2	3.73 b
P3	4.80 a*

*Different symbols show significant difference between values using dunca's multiple rage test at 0.05 Probability.

Table 25 :Average available P (ppm) after alfalfa harvesting at 30cm soil depth as affected by different P levels at locations 1 and 2.

Phosphorus treatment	Location 1		Location 2	
	Alfalfa	Sorghum	Alfalfa	Sorghum
P1	006.0 a	005.4 a	007.6 a	008.2 b*
P2	007.9 a	022.7 a	010.7 a	019.1 ab
P3	013.5 a	066.7 a	037.3 a	043.8 a

* Values within the same column with different symbols show significant differences between values using Duncan's Multiple Range Test at 0.05 probability level.

4.8.3 Phosphorus Available After Alfalfa Harvesting at Location 2

Table 25 shows P available at 30 cm soil depth after alfalfa harvesting as affected by different P treatments at location2. Average P available values were 7.6 , 10.37 and 37.3 ppm under **P1, P2** and **P3** respectively Statistical analysis showed no significant effect of the different P treatments on P available after harvesting because of high differences in P available among replicates within the same treatment due to spatial variability. High P available under P3 treatment was because of the high P application under P3 treatment. Under P3 treatment, P available after alfalfa harvesting was higher than initial P available in the soil before P fertilization while under P1 and P2 treatments, P available was lower.

4.8.4 Phosphorus Available After Sorghum Harvesting at Location 2

Table 25 shows P available at 30 cm soil depth after sorghum harvesting as affected by different P treatments at location 1. No significant differences in P available after sorghum harvesting between P1 and P2 and between P2 and P3 treatments were found while P available after sorghum harvesting was significantly higher under P3 treatment than under P1 treatment. P available after sorghum harvesting increased under P3 treatment (43.8 ppm) compared to P2 (19.1 ppm) and P1 (8.2 ppm) treatments by about 229.3% and 534.1% respectively. This is because of the high P application under P3 treatment. Under P3 and P2 treatments, P available after sorghum harvesting was higher than initial P available in the soil (13 ppm) before P fertilization, while under P1 treatment P available was lower.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. Deep contour furrows enabled the soil Profile to reach field capacity in the deep and shallow soil profiles.
2. Evapotranspiration of alfalfa at location 2 were significantly affected by different phosphorus levels,while evapotranspiration and seasonal water use at location 1 were not significantly affected by different phosphorus levels.
3. Evapotranspiration and seasonal water use of sorghum at both locations were significantly affected by different phosphorus levels. Sorghum in deep soil profile had significantly higher evapotranspiration than in shallower soil profile.
4. In deep soil profile, more than 59% of soil water extracted by alfalfa and sorghum was taken from the 0-45 cm depth regardless of **P** level and 0-15 cm depth had the highest percentage of soil water extraction (22.5%), while in shallow soil profile more than 45% of soil water extracted was taken from 0-30 cm depth regardless of **P** level and 0-15 cm depth had the highest percentage of soil water extraction about (32%).
5. In shallow soil profile, alfalfa treated with high **P** level (100 kg TSP/ha) had the greatest rooting depth (end of soil profile), and alfalfa treated with low **P** level (0 kg TSP/ha) had the lowest rooting depth, while in deep soil profile alfalfa root penetration reached wetting front (90-105 cm) depth under all **P** treatments because of the high initial **P** available in the soil (20 ppm)
6. In deep soil profile sorghum treated with **P3** had the greatest rooting depth (90cm), while sorghum treated with **P2** and **P1** had rooting depth of 75 cm.

In shallow soil profile sorghum treated with **P3** and **P2** had rooting depth of 70 cm (end of soil profile), while sorghum treated by **P1** had rooting depth of 60 cm.

7. Alfalfa and sorghum roots at both deep and shallow soil profiles were concentrated at the top 45 cm soil depth under various **P** levels.
8. In deep soil profile no significant effect of **P** levels on alfalfa dry-matter yield was obtained, while in shallow soil profile significant increase was obtained by **P3** treatment compared to **P2** and **P1** treatments.
9. `In deep soil profile significant increase in sorghum stover yield was obtained by **P3** treatment Compared to **P1** treatment, while at shallow soil profile **P** levels had no significant effect on sorghum store yield.
10. Phosphorus levels had no significant effect on sorghum grain yield at deep soil profile, while in shallow soil profile, no grains were produced.
11. Alfalfa dry-matter and sorghum stover yields at deep soil profile were significantly higher than in shallow soil profile.
12. Total Phosphorus uptake by alfalfa estimated as (kg/ha) was significantly increased with P3 treatment compared to **P2** and **P1** treatments.
13. In both deep and shallow soil profile, there were no significant effect of **P** treatments on phosphorus available after alfalfa and sorghum harvesting and the highest **P** available after harvesting was obtained under **P3** treatment in both locations for both plants and the lowest was obtained under **P1** treatment.

5.2 Recommendations

1. Deep contour furrows are appropriate soil surface treatment in soils with surface crust to bring soil profile to field capacity.
2. Deep soil are recommended for producing forage crops (alfalfa and sorghum) in soil profile at field capacity.
3. High phosphorus applications (45kg P_2O_5/ha) are recommended to increase alfalfa and sorghum stover yields under uniform soil conditions. Phosphorus will increase both root distribution and root penetration.

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APPENDIX A

Table 1. Rainfall distribution (mm) durig 1996-97 growing season.

Date	Rainfall amount (mm)
18/11/1996	17.0
26/11/1996	30.0
09/12/1996	03.0
13/12/1996	08.0
13/01/1997	20.5
16/01/1997	14.0
22/01/1997	23.5
29/01/1997	00.3
23/02/1997	08.0
24/02/1997	12.0
25/02/1997	08.0
03/03/1997	00.5
06/03/1997	03.0
15/03/1997	02.0
18/03/1997	02.0
19/03/1997	02.0
24/03/1997	01.0
Total	**154.8**

APPENDIX B

Table 1 ANOVA: Alfalfa evapotranspiration (mm) as affected by phosphorus levels at location (1).

Source		Df.*	M.S.*	F Value	Pr > F
Total		8			
Model	Rep.*	2	74.8	1.43	0.34
	T.*	2	47.8	0.92	0.47
Error		4	52.3		

Table 2 ANOVA:Sorghum evapotranspiration (mm) as affected by phosphorus levels at location (1).

Source		Df.	M.S.	F Value	Pr > F
Total		8			
Model	Rep.	2	014.96	0.34	0.73
	T.	2	164.89	5.15	0.07
Error		4	031.98		

Table 3 ANOVA: Alfalfa evapotranspiration (mm) as affected by phosphorus levels at location (2).

Source		Df.	M.S.	F Value	Pr > F
Total		8			
Model	Rep.	2	7.39	0.33	0.735
	T.	2	1826.20	82.07	0.0006
Error		4	22.25		

Table 4 ANOVA: Sorghum evapotranspiration (mm) as affected by phosphorus levels at location (2).

Source		Df.	M.S.	F Value	Pr > F
Total		8			
Model	Rep.	2	4.06	0.20	0.83
	T.	2	426.40	20.64	0.008
Error		4	20.66		

***Df: Dgree of Freedom**

***MS: Mean Squares**

***Rep: Replicate**

***T: Treatment**

APPENDIX C

Table 1: Actual Alfalfa yield (gram per plot) as affected by different P levels at location 1.

Phosphorus treatment	Replicate 1	Replicate 2	Replicate 3	Average
P1	38753	04241	00453	14482
P2	02753	01430	00781	01655
P3	00174	00379	01076	00543

Table 2: Actual sorghum stover yield (gram per plot) as affected by different P levels at location 1.

Phosphorus treatment	Replicate 1	Replicate 2	Replicate 3	Average
P1	2200	1517	2029	1915
P2	0339	3875	4038	2751
P3	3201	7044	8794	6346

Table 3: Actual sorghum grain yield (gram per plot) as affected by different P levels at location 1.

Phosphorus treatment	Replicate 1	Replicate 2	Replicate 3	Average
P1	0294.44	0212.79	0173.96	0227.06
P2	0029.33	0345.23	0775.48	0383.35
P3	0473.20	1898.93	1231.54	1201.22

Table 4: Actual Alfalfa yield (gram per plot) as affected by different P levels at location 2.

Phosphorus treatment	Replicate 1	Replicate 2	Replicate 3	Average
P1	1.41	0.36	1.75	1.17
P2	2.58	1.34	1.00	1.64
P3	5.88	2.67	0.86	3.14

Table 5: Actual sorghum stover yield (gram per plot) as affected by different P levels at location 2.

Phosphorus treatment	Replicate 1	Replicate 2	Replicate 3	Average
P1	0010.096	0076.294	0392.085	0159.492
P2	0701.536	0529.862	0261.143	0497.514
P3	0568.545	1117.686	0224.498	0636.910

Table 6: Actual Alfalfa yield (Kg per plot) for the first harvest of the second season as affected by different P levels at location 1.

Phosphorus treatment	Replicate 1	Replicate 2	Replicate 3	Average
P1	37.654	20.908	13.536	24.033
P2	07.770	17.599	12.722	12.697
P3	19.022	04.202	14.898	12.707

Table 7 Alfalfa seedling emergence percentage (location 1).

Phosphorus treatment	Replicate 1	Replicate 2	Replicate 3	Average
(1)	40.000	03.000	01.500	14.830
(2)	07.000	02.000	01.700	03.567
(3)	00.168	01.000	01.000	00.723

Table 8 Sorghum seedling emergence percentage (location 1).

Phosphorus treatment	Replicate 1	Replicate 2	Replicate 3	Average
(1)	22.08	22.20	21.28	21.85
(2)	04.08	19.56	30.60	18.08
(3)	19.32	31.76	31.80	27.63

Table 9 Alfalfa seedling emergence percentage (location 2).

Phosphorus treatment	Replicate 1	Replicate 2	Replicate 3	Average
(1)	0.092	0.028	0.068	0.063
(2)	0.076	0.044	0.036	0.052
(3)	0.064	0.040	0.016	0.040

Table 10 Sorghum seedling emergence percentage (location 2).

Phosphorus treatment	Replicate 1	Replicate 2	Replicate 3	Average
(1)	00.64	02.96	18.00	07.20
(2)	22.72	12.60	07.20	14.17
(3)	09.88	34.12	07.36	17.12

APPENDIX D

Table 1 ANOVA:Alfalfa dry-matter yield (ton/ha) as affected by phosphorus levels at location 1.

Source		Df.*	SS.*	M.S.*	F Value	Pr > F
Total		8	19.65			
Model	Rep.*	2	01.38	0.69	0.19	0.83
	T.*	2	03.80	1.90	0.53	0.63
Error		4	14.46	3.61		

C.V.= 63.4%

Table 2 ANOVA: Sorghum stover yield (ton/ha) as affected by phosphorus levels at location 1.

Source		Df.	SS.	M.S.	F Value	Pr > F
Total		8	0.63			
Model	Rep.	2	0.06	0.03	0.80	0.51
	T.	2	0.04	0.20	5.20	0.08
Error		4	0.16	0.04		

C.V.= 32.98%

Table 3 ANOVA: Sorghum grain yield (ton/ha) as affected by phosphorus levels at location 1.

Source		Df.	SS.	M.S.	F Value	Pr > F
Total		8	0.040			
Model	Rep.	2	0.005	0.002	1.20	0.39
	T.	2	0.025	0.013	6.24	0.06
Error		4	0.0008	0.002		

Table 4 ANOVA: Alfalfa dry-matter yield (ton/ha) as affected by phosphorus levels at location 2.

Source		Df.	SS.	M.S.	F Value	Pr > F
Total		8	0.087			
Model	Rep.	2	0.004	0.002	00.75	0.53
	T.	2	0.073	0.036	14.43	0.01
Error		4	0.010	0.002		

Table 5 ANOVA: Sorghum stover yield (ton/ha) as affected by phosphorus levels at location 2.

Source		Df.	SS.	M.S.	F Value	Pr > F
Total		8	0.019			
Model	Rep.	2	0.001	0.0003	0.18	0.84
	T.	2	0.010	0.0050	2.40	0.21
Error		4	0.008	0.0020		

C.V.= 34.8 %

***Df: Dgree of Freedom**

***SS: Sum of Squares**

***MS: Mean Squares**

***Rep: Replicate**

***T: Treatment**

APPENDIX E

Table (1) ANOVA: Total P uptake by alfalfa (kg/ha) as affected by P levels at location 1.

Source		Df.*	SS.*	MS.*	F.Yalue	Pr>F
Total		8	10.30			
Model	Rep.*	2	00.36	0.18	1.2	0.40
	T.*	2	02.43	1.21	7.7	0.04
Error		4	08.90	2.20		

c.v.=26.4%

Table (2)ANOVA: P available (ppm) after alfalfa harvesting as affected by phosphorus levels at location 1.

Source		Df.	SS.	MS.	F.Value	Pr>F
Total		8	167.0			
Model	Rep.	2	019.8	09.9	2.76	o.59
	T.	2	090.6	45.3	0.60	0.17
Error		4	065.6	16.4		

c.v.= 44.46%

Table (3)ANOVA: P available (ppm) after alfalfa harvesting as affected by phosphorus levels at location 2.

Source		Df.	SS.	MS.	F.Value	Pr>F
Total		8	3125.2			
Model	Rep.	2	0763.1	381.5	1.99	0.25
	T.	2	1597.1	798.5	4.18	0.15
Error		4	0765.0	191.3		

c.v = 74.44%

Table (4)ANOVA: P available (ppm) after sorghum harvesting as affected by phosphorus levels at location 1.

Source		Df.	SS.	MS.	F.Value	Pr>F
Total		8				
Model	Rep.	2	2147.1	1073.6	1.11	0.41
	T.	2	6001.7	3000.9	3.09	0.15
Error		4	3880.9	0970.2		

c.v. = 98.57%

Table (5)ANOVA: P available (ppm) after sorghum harvesting as affected by phosphorus levels at location 2.

Source		Df.	SS.	MS.	F.Value	Pr>F
Total		8				
Model	Rep.	2	0193.4	096.7	0.60	0.59
	T.	2	1997.2	998.6	6.15	0.06
Error		4	0649.3	162.3		

***Df: Dgree of Freedom**

***SS: Sum of Squares**

***MS: Mean Squares**

***Rep: Replicate**

***T: Treatment**

الملخص

استجابة البرسيم الحجازي والذرة البيضاء للتسميد الفوسفاتي في تربة الموقر عند السعة الحقلية

إعداد

أشرف متري البقاعين

المشرف

د. إبراهيم غاوي

المشرف المشارك

د. بطرس حتر

التسميد الفوسفاتي يشجع نمو الجذور واستطالتها وبالتالي يعزز من اختراق الجذور للتربة لاعماق اكبر وبالتالي استخدام الماء والمغذيات من هذه الاعماق.

اجريت تجربة حقلية في محطة البحوث التابعة للجامعة الاردنية بالقرب من قرية الموقر خلال موسم ١٩٩٦-١٩٩٧ م حيث تم اختيار موقعين احدهما ذو تربة عميقة المقد (١,٣٥م) والاخر ذو تربة ضحلة المقد (٠,٧٠م).

وكان الهدف من هذه التجربة اختيار امكانية زراعة محاصيل علفية مثل البرسيم الحجازي (الفصة) والذرة البيضاء على المياه المخزنة في مقد التربة عند حد السعة الحقلية، ودراسة تأثير التسميد الفوسفاتي على نمو جذور هذه المحاصيل.

لقد تم استخدام تصميم القطاعات العشوائية الكاملة والتي اشتملت على عامل التسميد الفوسفاتي من خلال ثلاث معدلات اضافة هي صفر و ٥٠ و ١٠٠ كغم من سماد السوبر

فوسفات الثلاثي لكل هكتار. في التربة ضحلة المقد اخترقت جذور البرسيم الحجازي (الفصة) التربة الى عمق اكبر باضافة السماد الفوسفاتي بتركيز عالي بينما في التربة عميقة المقد فان جذور البرسيم الحجازي اخترقت التربة الى الاعماق التي وصلت اليها المياه في التربة الى حد السعة الحقلية بغض النظر عن معدلات اضافة السماد الفوسافاتي. في التربة عميقة المقد اخترقت جذور الذرة البيضاء التربة الى عمق اكبر باضافة السماد الفوسفاتي بتركيز عالي مقارنة بالاضافة المتوسطة والشاهد، بينما في التربة ضحلة المقد فقد اخترقت جذور الذرة البيضاء التربة الى نهاية مقد التربة (٠,٧م) باضافة السماد الفوسفاتي بتراكيز عالي ومتوسط بينما وصلت الى عمق ٠,٦٠ م في حالة الشاهد.

في التربة عميقة المقد لم تظهر النتائج فروقات معنوية في التبخرو النتح لمحصول البرسيم الحجازي نيتجة اضافة معدلات مختلفة من السماد الفوسفاتي بينما في التربة ضحلة المقد فقد اظهرت النتائج فروقات معنوية في قيم التبخر والنتح نتيجة اضافة معدلات مختلفة من السماد الفوسفاتي.

في كلا التربتين اظهرت النتائج فروقات معنوية في قيم التبخر والنتح لمحصول الذرة البيضاء نتيجة استخدام معدلات مختلفة من السماد الفوسفاتي.

في التربة عميقة المقد لم تظهر فروقات معنوية في انتاج البرسيم (على اساس الوزن الجاف) نتيجة اضافة معدلات مختلفة من السماد الفوسفاتي، بينما في التربة ضحلة المقد فقد اظهر انتاج البرسيم الحجازي زيادة معنوية باضافة السماد الفوسفاتي بتركيز عالي مقارنة مع الاضافة المتوسطة والشاهد.

في التربة عميقة المقد اظهر انتاج الذرة البيضاء من القشر ومن الحبوب زيادة معنوية باضافة السماد الفواسفاتي بتركيز عالي مقارنة مع الشاهد ولم تظهر فروقات معنوية في الانتاج

باضافة السماد الفوسفاتي بتركيز عالي مقارنة مع الاضافة المتوسطة وكذلك بين الاضافة المتوسطة والشاهد بينما في التربة ضحلة المقد لم تظهر فروقات معنوية في انتاج الذرة البيضاء من القش نتيجة نتيجة استخدام معدلات مختلفة من السماد الفوسفاتي ولم تصل الذرة البيضاء الى مرحلة تكوين العثاكيل (العرانيس) وانتاج الحبوب لجميع المعاملات.

في كلا التربتين لم تظهر فروقات معنوية في نسبة الفسفور المتبقية بعد الحصاد لمحصول البرسيم الحجازي نتيجة استخدام معدلات اضافة مختلفة من السماد الفوسفاتي بينما في التربة ضحلة المقد ظهرت زيادة معنوية في نسبة الفسفور المتبقي بعد حصاد محصول الذرة البيضاء نتجية استخدام السماد الفوسفاتي بتركيز عالي مقارنة مع الشاهد بينما في التربة عميقة المقد لم تظهر فروقات معنوية في نسبة الفسفور المتبقي بعد حصاد محصول الذرة البيضاء نتيجة اضافة معدلات مختلفة من السماد الفوسفاتي.

كنتيجة نهائية، دلت النتائج ان التربة ذات المقعد العميق والتي تختزن كميات مياه الى اعماق اكبر مع اضافة السماد الفوسفاتي (السوبر فوسفات الثلاثي) بمعدل ١٠٠ كغم لكل كهتار هي افضل توليفة للاستخلام في زراعة المحاصيل العلفية الصيفية (البرسيم المجازي والذرة البيضاء) في تربة الموقر اعتمادا على المياة المخزنة في مقد التربة عند السعة الحقلية.