Effect of Cover Crop on Soil Physical and Chemical Properties of an Alfisol in the Sudan Savannah of Burkina Faso.

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ABSTRACT

The effect of several leguminous and graminaceous cover crops on soil physical and chemical properties was studied on a moderately eroded Alfisol in the Sudan Savannah of Burkina Faso during the growing seasons of 1986 and 1987. Cover crops sown in 1986 were Macroptilium artropurpureum, M. lathyroides, Vigna radiata var. radiate, Cajanus cajan, Alysicarpus vaginalis, Lablab purpureus, Psophocarpus palustris, Digitaria ciliaris and Echinochloa colona. Maize (Zea mays), cowpea (V. unguiculata) and a bare fallow were included in the trial for comparison. After harvest of maize and cowpea, following farmer practice, crop residues were removed from the plots. Cover crop residue, however, was retained as in situ mulch. Maize was sown on all plots in 1987 following cultivation of a 0.20m wide strip to a depth of 0.05m within plant rows (strip tillage). No herbicide was used at any time during the trial.

Soil properties measured were bulk density, water infiltration, particle size distribution, soil OM, carbon, nitrogen, Bray-1-P, exchangeable Ca, Mg, Na and K, total CEC, soil water potential and soil water retention at depths of 0.30 and 0.60m, and soil temperature at a depth of 30-mm. Apparent pore size distribution at depths of 0.30m and 0.60m was inferrred from porosity and soil water retention characteristics. Ground cover of cover crops was measured in 1986. Root growth of cover crops in 1986 and of maize in 1987 was measured by sampling with an auger at depths of 0-0.10m, 0.10-0.20m, 0.20-0.30m, 0.30-0.50m and 0.50-0.75m, and 'washing' the samples over sieves with aperture diameters of 0.2 mm.

Clay content in treatments sown to C. cajan, Z. mays, A. vaginalis and bare fallow were greatest due to loss of topsoil and exposure of the clay-rich subsoil. Sowing of M. artropurpureum and M. lathyroides resulted,

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in general, in greater levels of soil OM, carbon, C/N ratio and exchangeable K, higher infiltration rates, greater proportion of macropores (pore radius > 14.3 µm) and soil matric potential at depths of 0.30m and 0.60m, and higher subsoil root growth, grain and dry matter yields of maize in 1987. Significant increases of the above soil properties, root growth and yield of maize were also obtained by sowing of P. palustris, L. purpureus and E. colona Soil degradation was greatest where treatments in 1986 were either C. cajan or bare fallow. Sand and silt contents, exchangeable Ca, Mg, and Na, total CEC, soil N, Bray-1-P, and total porosity were not significantly affected by cover crop. Soil ameliorative ability of cover crop was primarily related to rapidity of formation of ground cover and subsoil root density. In terms of soil ameliorative abilities of the cover crops studied, M. lathyroides and M. artropurpureum were therefore, the most appropriate for the Sudan savannah of Burkina Faso.

INTRODUCTION

A feature of the upland soils of the West African semi-arid tropics (WASAT) (primarily Alfisols) is high soil compaction (Perrier, 1986; Jones and Wild, 1975) Soil bulk density increases from 1.4 Mg m^{-3} (porosity = 47% m^3 m^{-3}) at the surface to 1.8 Mg m^{-3} (porosity = 32% m^3 m^{-3}) at a depth of 1.00m (Perrier, 1986).' Available water' (i.e. water storage capacity) is, therefore, low. The compacted subsoil also results in low or negligible root densities in the subsoil (Nicou and Charreau, 1985; Hulugalle, 1988). The soil volume from which water extraction can occur is, therefore small. The effects of the short-term droughts which frequently occur during the growing season in the WASAT (Jones and Wild, 1975; Roose, 1981; Muleba, 1986) are, consequently, greatly exacerbated.

Research on ameliorating soil compaction and improving soil water storage in the WASAT has, in the past, concentrated primarily on intensive tillage and soil modification systems (Fournier, 1967; Nicou and Charreau, 1985; Matlon and Spencer, 1984; Rodriguez, 1986; Hulugalle, 1988). Adoption of such systems by farmers in the WASAT has been poor, primarily due to lack of capital and labour (Matlon and Spencer, 1984; FSU/SAFGRAD, 1987). Alternative systems of soil amelioration which have been studied include the use of crop residues as *in situ* (Fournier, 1967; Roose 1981; Nicou and Charreau, 1985; Perrier, 1986). While *in situ* crop residue mulch in sufficient quantity is highly effective in reducing water runoff and improving soil properties (Fournier, 1967; Roose, 1981; Nicou and Charreau, 1985), production of insufficient residues by crops in the WASAT and their utilisation for stock feed and building materials (FSU/SAFGRAD, 1987; Dugue, 1985; Prudencio, 1987) means that at present use of crop residue as mulch is not a viable proposition for the WASAT.

The problem of insufficient mulch has been solved in the North Australian semi-arid tropics and in the more humid regions (1000-1500mm rainfall) of the West African and Asian tropics by utilizing no-tillage or minimum tillage systems alternating with periods of legume or grain leys (Lal, 1983; Jones and McCowan, 1984; Abeyratne; 1956). Such systems of soil management increase crop yield while concurrently improving soil properties (Lal, 1983; Wilson et el., 1982). Improvements in soil properties include increases in soil porosity, water infiltration, profile water content, soil water retentior organic matter, exchangeable bases, total cation exchange capacity, pH, nitrogen and available phosphorus, and decreases in soil temperature (Lal, 1983; Wilson et al., 1982; Hulugalle and Lal, 1986). Such improvements are related primarily to inclusion of deep-rooted cover crops in the crop rotation (Wilson et al ., 1982; Lal, 1983; Hulugalle and Lal, 1986).

The degree of soil amelioration is, however, dependent upon the cover crop used. In the humid Alfisols of West Africa leguminous cover crops were superior to grasses. Among leguminous cover crops ameliorative ability of Psophocarpus palustris was superior to those of Pueraria phaseoloides, Stylosanthes guianensis, Stizolobium deerangium and Centrosema pubescens (Wilson et al., 1982). In Northern Australia Stylosanthes hamata cv. verano has shown promise as a cover crop (Jones and McCowan, 1984). Little published information exists, however, on suitable cover crops for the Sudan and Sahel savannahs of the WASAT. The objective of this study, therefore, was to evaluate several leguminous and graminaceous cover crops in terms of their soil amelioration abilities for inclusion in rotations with cereal crops under minimum (strip) tillage in the Sudan savannah of Burkina Faso.

MATERIALS AND METHODS

The experiment was conducted during the growing seasons of 1986 and 1987 at Kamboinse Research Station, 14 km north-east of Ouagadougou, Burkina Faso (12) 28' N, 1° 33' W, 300m ASL). Mean annual rainfall is 762mm (Perrier, 1986) with the rainy season extending from June to September. Annual rainfall in 1986 and 1987 was 813.6 and 652.3 mm, respectively. The soil at the experimental site was a kaolinitic, hyperthermic oxic Paleustalf with a sandy clay loam topsoil and sandy clay subsoil (Smaling, 1985). Particle size analysis indicated that the surface 0.10m consisted of 32% sand, 45% silt and 23% clay. CEC (IN Ammonium accetate, pH 7) was to m mol (+) kg^{-1} with Ca, Mg and K accounting for 20, 7 and 4 m mol (+) kg^{-1}, respectively. Soil pH (H_2O) and organic matter were 6.0 and 0.6%, respectively. The experimental site had been previously under a maize monoculture for a period of 5 years. Few soil conservation measures has been taken and the site was, therefore, moderately eroded.

The experimental treatments in 1986 were maize (Zea mays cv. Safitta-2), bare fallow, cowpea (Vigna unguiculata cv. TVx 3236), jungle rice (Echinochloa colona cv. Kamboinse local), fonio (Digitaria ciliaris cv. Kamboinse local), wild winged bean (Psophocarpus palustris), pigeonpea (Cajanus cajan), tropical alsike clover (Alysicarpus vaginalis), mung bean (Vigna radiata var. radiata), siratro (Macroptilium artropurpureum cv. Siratro), M. lathyroides cv. Kamboinse local, and Lablab or hyacinth bean (Lablab purpureus cv. Highworth). The experimental design was a randomized complete block with 4 replications. Plot size was 4 x 5 m. All plots were cultivated to a depth of 0.05m with 'daba' handhoes prior to planting. Fertilizer was broadcast as 200 kg ha^{-1} of 13:20:15 NPK at planting. In addition 100 kg ha^{-1} of urea was applied to all maize plots as a side-dressing at 30 days after planting (DAP). Plant densities, spacings and populations are shown in Table 1. Sowing was done on 13 June 1986. After harvest at 90 DAP,

Table 1. Plant densities and populations of cover crops in 1986.

Cover Crop	Plant Spacing(m)	Plant density (Plants) $(hill^{-1})$	Plant population (Plants) (ha^{-1})
Zea mays	0.75 x 0.25	1	5.33×10^4
Vigna unguiculata	0.75 x 0.25	2	1.07×10^5
Bare fallow	-	0	0
Cajanus cajan	0.75 x 0.25	1	5.33×10^4
Digitaria ciliaris	0.75 x 0.01	1	1.33×10^6
Echinochloa colona	0.75 x 0.01	1	1.33×10^6
Alysicarpus vaginalis	0.75 x 0.01	1	1.33×10^6
V. radiata var. radiata	0.75 x 0.25	2	1.07×10^5
Macroptilium artropurpureum	0.75 x 0.01	1	1.33×10^6
M. lathyroides	0.75 x 0.01	1	1.33×10^6
Psophocarpus palustris	0.75 x 0.25	2	1.07×10^5
Lablab purpureus	0.75 x 0.25	2	1.07×10^5

following local farmer practice, maize and cowpea residues were removed from all plots. Plant residues from all other treatments were retained as in situ mulch.

Maize (Zea mays (L.) cv. Safita 2) was sown in all plots in 1987 at spacings of 0.25 x 0.75m at a population of 5.33 x 10^4 plants ha^{-1}. Prior to planting a 0.20m strip was cultivated to a depth of 0.05m within plant rows with 'daba' handhoes. Fertilizer was applied at the same time at a rate of 200 kg ha^{-1} of 13:20:15 NPK. Urea was applied as a side-dressing at a rate of 100 kg ha^{-1} at 30 dap. All plots were weeded at 10 and 40 DAP with 'daba' handhoes. An additional weeding was required at 55 DAP on plots sown to E. colona and D. ciliaris in 1986. Care was taken to minimize disturbance of the residue mulch during weeding. At no time during the trial were weeds controlled by herbicide application. Maize was harvested at 85 DAP in 1987.

Ground cover was measured following the meter-rule method of Adams and Arkin (1977), at 47, 64 and 82 DAP in 1986. Root growth was measured at 46 DAP in 1986 and 37 DAP in 1987 at depths of 0-0.10, 0-10-0.20, 0.20-0.30, 0.30-0.50 and 0.50-0.75 m by sampling within plant rows with an 'Edelman' or 'Dutch' auger of a diameter of 75 mm. The roots were separated from the soil by 'washing' over a sieve with apertures of 0.2 mm, and oven-dried at 80°C over a period of 48h (Bohm, 1979). The results were analyzed following log transformation (Brown and Scott, 1984).

Soil bulk density was measured on cores of 50 mm diameter and 50 mm high taken from the 0-0.05m depth within and between plant rows in August and September 1986, and June 1987; and from the 0.28-0.33m and 0.58-0.63m depths within and between plant rows in October 1987. In addition bulk density in the 0-0.10m depth between plant rows was measured in August 1987 on cores of 70 mm diameter and 100 mm high. At each time of sampling 4 cores were taken from each plots. Total porosity was derived from the relationship, Total porosity = 1 - (bulk density/particle density) where particle density was taken to be 2.65 Mg m^{-3} (Marshall, 1959; Campbell, 1985). Water infiltration over 2 hours wasmeasured with a double-ring infiltrometer in January and October 1987. Diurnal variation in soil temperature at a depth of 30-mm was measured within plant rows with mercury-in-glass bent-stem soil thermometers at 24, 25, 26, 45, and 70 DAP in 1987. Due to insufficient thermometers at 24, 25 and 26 DAP the trial was split into 3 groups and soil temperature measured over 3 days, with that in plots where maize was planted in 1986 being measured on all 3 days. Dial-type vacum-gauge tensiometers were installed at depths of 0.30m and 0.60m in all plots during 1987 and observations of soil water potential were made at 0700h every 2-3 days during the growing season. For reasons of clarity only observations made at 7, 14, 21, 28, 32, 39, 46, 56, 63, and 70 DAP have been presented (Figs 6 and 7). Following maize harvest, sub-plots of 10 m^2 in each plot were saturated to a depth of 0.60m and *in situ* water retention curves derived following Bonsu and Lal (1982) for the 0.30m and 0.60m depths. Apparent pore size distribution was inferred from total porosity and soil water retention characteristics using the surface tension relationship $h = 0.298/d$ where h is soil water potential (-cm water) and d is pore diameter (cm).

Composite soil samples were obtained from the 0-0.05m depth of all plots in March 1987 and analyzed for particle size distribution (hydrometer method) (Klute, 1986), soil organic matter and carbon (Walkley-Black method), pH (1:2.5) soil: water suspension), exchangeable Ca, Mg, K and Na, and total CEC (IN ammonium acetate, pH 7), total N (Kjeldahl analysis) and Bray-1-P (Page *et al.,* 1982).

All data was analyzed following analysis of variance for RCB design. Means were separated by Duncan's Multiple Range Test (Little and Hills, 1978; Petersen, 1977).

Table 2. Effect of depth on root weight per unit area of cover crop at 46 DAP in 1986.

Cover crop	Root growth per unit area (kg ha^{-1})				
	0-0.10m	0.10-0.20m	0.20-0.30m	0.30-0.50m	0.50-0.75m
Zea mays	620a	510a	580a	260a	0d
Vigna unguiculata	860a	350a	130bc	100a	0d
Cajanus cajan	390a	450a	180abc	80a	0d
Digitaria ciliaris	860a	940a	240ab	220a	25c
Echinochloa colona	600a	810a	430a	220a	75bc
Alysicarpus vaginalis	530a	420a	300a	120a	0d
V. radiata var. *radiata*	640a	300a	90c	100a	0d
Macroptilium artropurpureum	480a	260a	230ab	260a	125a
M. lathyroides	1100a	620a	510a	440a	175a
Lablab purpureus	510a	400a	260ab	280a	100ab
Phosphocarpus palustris	550a	420a	330a	600a	120a
$P <$	NS	NS	0.05	NS	0.01

1. Values within the same column followed by the same letter do not differ significanly at the 5% level of probability (Duncans Multiple Range Test).

RESULTS AND DISCUSSION

Growth of cover crops during 1986

Vegetative growth measured as ground cover occurred most rapidly with Lablab purpureus,, Echinochloa colona and Macroptilium artropurpureum (Fig. 1). Growth of Digitaria ciliaris and Psophocarpus palustris although initially slow, increased subsequently such that ground cover at 65 DAP was similar to L. purpureus, E. colona and M. artropurpureum. The slowest rate of growth was shown by Cajanus cajan and Alysicarpus vaginalis.

Root growth measured at 46 DAP showed that subsoil (X 0.30m) root densities were low in all crops (Table 2). This is due to the high density subsoil (bulk density 1.65 Mg m^{-3}) which is characteristic of the Alfisols in the West African Sudan savannah (Jones and Wild, 1975; Perrier, 1986). Among cover crops root density in the 0.30-0.75 m depth was greatest with M. artropurpureum, M. lathyroides, L. purpureus and P. palustris. Root density at this depth was lowest in Vigna unguiculata, V. radiata, C. cajan and A. vaginalis.

Soil properties

particle size distribution

Sand and silt contents in the surface 0.05m were not affected significantly by the preceding cover crop, whereas clay content was (Table 3). Mean sand and silt contents were 36.6% and 47.2%, respectively. Clay content was affected by cover crop such that a low degree of ground cover earlier in the season resulted in a greater clay content in the surface 0.05m thus:

Clay (%) = 20.50 - 0.10 GC, $r = -0.66^{***}$, $n = 48$;

where GC is ground cover (%) at 47 DAP. In treatments which did not form a ground cover rapidly (eg. bare fallow, C. cajan, A. vaginalis), therefore, loss of topsoil occurred such that the clay-rich subsoil (Smaling, 1985) became exposed.

Table 3. Effect of preceding cover crop on clay content, soil organic matter (OM), organic carbon (C), carbon/nitrogen ratio (C/N), pH and exchangeable potassium (K) in the 0-0.05 m depth on 10 March 1987.

Preceding cover Crop	Clay (%)	OM (%)	C (%)	C/N	pH	Exch. K (m mol (+) kg^{-1})
Zea mays	17.6ab	0.39d	0.23d	5.5c	5.4c	1.9c
Vigna unguiculata	14.1c	0.60bc	0.35bc	9.4ab	5.6bc	1.7d
Bare fallow	19.5ab	0.36d	0.21d	5.2c	5.6bc	2.2bcd
Cajanus cajan	20.1 a	0.56bcd	0.32bcd	7.9abc	5.6bc	2.3bcd
Digitaria ciliaris	15.6b	0.79abc	0.49abc	10.6 ab	6.0a	2.7abc
Echinochloa colona	14.1c	0.46cd	0.27cd	5.6c	5.9ab	3.5a
Alysicarpus vaginalis	17.8abc	0.39d	0.23d	5.0c	5.7abc	2.5bcd
V. radiata var. *radiata*	15.4bc	0.66abcd	0.38abcd	8.0abc	6.0ab	2.3bcd
Macroptilium artropurpureum	15.6bc	0.96a	0.57a	10.7a	6.1a	3.1ab
M. lathyroides	13.7c	0.79abc	0.49abc	10.2ab	6.0ab	2.2bcd
Lablab purpureus	13.4c	0.82ab	0.47ab	10.2ab	5.9abc	2.5bc
Psophocarpus palustris	17.0abc	0.63abcd	0.37abcd	7.1bc	5.7ab	2.3bcd
P $<$	0.05	0.01	0.01	0.01	0.01	0.05

1. Values within the same column followed by the same letter do not differ significantly at the 5% level of probability (Duncans Multiple Range Test).

soil organic matter (OM), carbon (C), nitrogen (N), C/N ratio, pH and Bray-1-P.

Soil N and Bray-1-P were not affected significantly by the preceding cover crop. Mean soil N and Bray-1-P were 0.046% and 260.8 ppm, respectively. Soil OM, C, C/N and pH were significantly affected by the preceding cover crop (Table 3). High values of OM, C, C/N and pH were observed in plots which had been planted to *D. ciliaris, M. artropurpureum, M. lathyroides* and *Lablab purpureus.* Lowest values of OM, C, C/N and pH were shown where the preceding treatment was *Zea mays,* bare fallow, and *A. vaginalis.* Low values of OM, C and C/N were also shown by plots planted to *E. colona* in 1986, and suggests that a high rate of N mineralization occurred in these plots (Sanchez, 1976). The high N depletion rates of *E. colona* casts doubt,. therefore, on its value as a cover crop under condition of low fertility. Ground cover formation and mulch production by *E. colona* was, however, high (Fig. 1). Soil OM, C, and C/N ratio were related primarily to ground cover at 47 DAP (GC, %), and pH to soil OM (%) thus:

$OM^{1.} = 0.44 + 5.28 \times 10^{-3}$ GC, r = 0.54***, n = 44;

$C^{1.} = 0.26 + 2.81 \times 10^{-2}$ GC, r = 0.52***, n = 44;

$C/N^{1.} = 5.73 + 6.06 \times 10^{-2}$ GC, r = 0.66***, n = 44,

pH = 5.44 + 0.57 OM, r = 0.49***, n = 48.

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1. Data from plots planted to *E. colona* were deleted from these equations.

exchangeable Ca, Mg, K and Na, and total cation exchange capacity (CEC)

Exchangeable Ca, Mg, Na and total CEC were not significantly affected by preceding cover crop, whereas K was (Table 3). Mean Ca, Mg, Na and total CEC in the surface 0.05m were 14.8, 4.8, 1.4 and 31.3 m mol (+) kg^{-1}. Exchangeable K levels were lowest in plots planted to Z. mays and V. unguiculata in 1986; i.e. treatments from which, following former practice, all crop residues were removed after harvest, and highest where the preceding cover crops were E. colona and M. artropurpureum. Ca, Mg, Na and total CEC (m mol (+) (kg^{-1}) were related primarily to clay content (%), and exchangeable K to OM (%) thus:

exch. Ca = 0.96 Clay - 1.07; r = 0.63***; n = 48;

exch. Mg = 0.49 Clay - 3.06; r = 0.72***, n = 48;

exch. Na = 0.29 + 7.23 x 10^{-2} Clay; r = 0.52***, n = 48;

Total CEC = 2.25 Clay - 4.28; r = 0.80***, n = 48;

exch. K = 1.9 + 0.84 OM; r = 0.34*, n = 48.

Exposure of the clay - rich subsoil has therefore, resulted in increasing the availability of exchangeable Ca, Mg, Na and total CEC to the crops. Exchangeable K was, however, dependant upon the soil organic matter formed by the preceding cover crop.

porosity and water infiltration

Porosity did not differ significantly among treatments in the 0-0.05m depth during August and September 1986, and June 1987, in the 0-0.10m depth during August 1987, and in the 0.28-0.33m and 0.58-0.63m depths during October 1987. Mean porosities (m^3 m^{-3}%) in the 0-0.05m depth during August and September 1986, and June 1987, in the 0-0.10m depth during August 1987 and in the 0.28-0.33m and 0.58-0.63m depths during October 1987 were 47.17%, 45.28%, 45.66%, 43.02%, 37.74% and 35.09%, respectively.

Infiltration rate at 2 h after commencement of inctiltration (terminal infiltration rate) in January 1987 was lowest in treatments where either ground cover was low or crop residue removed after harvest (Table 4). Infiltration was, however, lowest in plots sown to Z. mays, V. unguiculata, bare fallow and C. cajan. Infiltration rate at 2 hours (dI/dt, mm h^{-1}) in January 1987 was related primarily to the ratio of clay (%) and OM (%) in the surface 0.05 m thus:

$$\frac{dI}{dt} = 174.92\ e^{-2.30 \times 10^{-2}\ (Clay/OM)},\quad r = -0.51^{***},\quad n = 48.$$

Surface crust formation is determined primarily by clay and OM contents (Campbell, 1985; Perrier, 1986). Crust formation was, theredore, lower and infiltration rate greater in treatments which had low clay and high OM contents. By October 1987, however, significantly decreases infiltration rate had occurred in most treatments. Relatively high infiltration rates were, nonetheless, maintained in treatments sown to L. purpureus and M. lathyroides. Residues of these cover crops are woody, and hence, breakdown rates of residue mulch are slower. Protection of the soil surface from the erosive effects of hihg intensity rainfall (Lal, 1983, Perrier, 1986) is, consequently, possible for a longer period than with crop residues which are of a less woody nature. Crust formation was, therefore, lower and infiltration rates higher during October 1987, in treatments sown to L. purpureus and M. lathyroides in 1986.

diurnal variation of soil temperature at a depth of 30-MM

Soil temperatures at a depth of 30-mm were, in general, lowest in treatments sown to M. artropurpureum, M. lathyroides and L. purpureus, and greatest in treatments sown in Z. mays, C. cajan and bare fallow in 1986 (Figs. 2 and 3). These differences are likely to be due to differences in crust formation, which in turn are caused by degree of ground cover and levels of clay and OM in the soil surface. Surface soil temperatures in the WASAT are highly correlated to crust formation (Perrier, 1986).

Table 4. Effect of preceding cover crop on infiltration rate at 2h after commencement of infiltration and temporal decreases of the same [1].

Preceding cover crop	Infiltration rate (mm h^{-1})		Decrease in infiltration rate (mm h^{-1})
	January 1987	October 1987	
Zea mays	76.0bc	46.7cd	29.3cd
Vigna unguiculata	80.0bc	72.8b	7.2cd
Bare fallow	15.2d	15.0d	0.2cd
Cajanus cajan	63.9cd	54.5cd	9.4cd
Digitaria ciliaris	99.9bc	55.1cd	44.8bc
Echinochloa colona	168.0a	57.6 cd	110.4ab
Alysicarpus vaginalis	91.9 bc	74.5bc	17.4cd
V. radiata var. *radiata*	91.8 bc	55.8cd	36.0cd
Macroptilium artropurpureum	156.0a	35.6cd	120.4a
M. lathyroides	123.9ab	154.5a	-30.6
Lablab purpureus	167.7a	117.7ab	50.0abc
Psophocarpus palustris	112.0abc	57.2cd	54.8abc
P <	0.01	0.01	0.01

1. Values within the same solumn followed by the same letter do not differ significantly at the 5% level of probability (Duncan's Multiple Range Test).

apparent pore size distribution and soil matric potential at depths of 0.30m and 0.60m

Proportion of macropores (pore radius, $r > 14.3 \mu m$) was greatest ($P < 0.01$) and micropores ($r < 2 \mu m$) lowest ($P < 0.01$) at a depth of 0.30m in treatments sown to M. artropurpureum, M. lathyroides, P. palustris, V. radiata and L. purpureus (Fig. 4), and at a depth of 0.60m in treatments sown to M. lathyroides, M. artropurpureum, L. purpureus, E. colona and P. palustris (Fig. 5) in 1986. Proprotion of mesopores ($r = 2\text{-}14.3 \mu m$) was not significantly affected by cover crop. Pore size distributions at depths of 0.30m and 0.60m were related primarily to root densities in the 0.20-0.50m and 0.50-0.75m depths, respectively, thus:

$$0.30m : \varepsilon_m = 31.54 + 2.11 \ln R_w, \; r = 0.53^{***}, \; n = 48,$$

$$0.60m : \varepsilon_m = 32.45 + 0.72 \ln R_w, \; r = 0.64^{***}, \; n = 48;$$

where ε_m is proportion of macropores (%) and R_w is root weight per unit area (kg ha^{-1}). Root growth of the preceding cover crop has, therefore, significantly increased the proportion of macropores at depths of 0.30m and 0.60m.

Soil matric potential in the 0.30m and 0.60 m depths was highest throughout the growing season in treatments sown to M. artropurpureum, M. lathyroides, L. purpureus and P. palustris in 1986 (Figs. 6 and 7). After the onset of heavy rains at 30 DAP in 1987, increases in matric potential in treatment sown to E. colona were also observed. Among the above treatments, however, soil matric potential was, in general, highest in the 0.30m depth where M. artropurpurpureum and M. lathyroides were sown, and in the 0.60m depth where M. artropurpureum was sown in 1986. Soil matric potential was lowest in the 0.30m depth in treatments which had included C.cajan and bare fallow. In the 0.60m depth matric potentials above -60 kPa occurred only in treatments sown to M. artropurpureum, M. lathyroides, P. palustris, E. colona, L. purpureus and D. ciliaris in 1986. Seasonal soil matric potential at depths of 0.30m and 0.60 was related primarily to pore size distribution and infiltration rate thus:

$$0.30: \ \bar{\Psi}m = 225.56\, e^{-2.12 \times 10^{-2} \varepsilon' - 7.79 \times 10^{-3} (dI/dt)} \quad R = 0.70^{***}, n = 48;$$

$$0.60\,m: \ \bar{\Psi}_m = 103.54\, e^{-4.92 \times 10^{-3} \varepsilon' - 3.9 \times 10^{-3} (dI/dt)}, \quad R = 0.56^{***}, n = 48,$$

where $\bar{\Psi}m$ is mean seasonal soil matric potential (-kPa), ε' is the sum of macro and mesopores (i.e. $r \geq 2\mu m$) (%) and dI/dt is the mean of terminal infiltration rates measured during January and October 1987 (mm h^{-1}).

Maize root growth during 1987

Preceding cover crop did not have any significant effect on maize root growth during 1987 at depths of 0-0.10m, 0.10-0.20m and 0.20-30m (Table 5). Root growth in the 0.30-0.50m and 0.50-0.75m depths were, however, affected such that greatest values were observed in treatments sown to M. artropurpureum, M. lathyroides and P. palustris, and lowest values in treatments sown to bare fallow, C. cajan, Z. mays and A. vaginalis in 1986. Root growth ($\acute{R}_W$, kg ha^{-1}) at these depths were related primarily to proportion of macropores (εm, %) thus:

$$0.30\text{-}0.50m^{1.}: Rw = 1.95 \times 10^{-2}\, e^{0.15\varepsilon m}, \quad r = 0.48^{***}, n = 48;$$

$$0.50\text{-}0.75m^{2.}: R_W = 1.03 \times 10^{-9}\, e^{0.63\varepsilon m}, \quad r = 0.63^{***}, n = 48.$$

Root growth of the preceding cover crop has, therefore, significantly affected the proportion of macropores in the subsoil, which in turn has affected subsoil root growth of the following maize crop. Increases in depth and density of subsoil root growth suggests that the maize crops which followed cover crops such as M. lathyroides, M. artropurpureum and P. palustris had a potentially greater store of soil water and nutrients available for consumption than those which followed C. cajanus, bare fallow or Zea mays.

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1. ε m in the 0.30m depth 2. ε m in the 0.60m depth.

Table 5. Effect of preceding cover crop on variation of root weight per unit area of maize with depth at 37 DAP in 1987[1].

Preceding cover crop	Root weight per unit area (kg ha^{-1})				
	0-0.10m	0.10-0.20m	0.20-0.30m	0.30-0.50m	0.50-0.75m
Zea mays	300a	120a	87a	8d	0.3cd
Vigna unguiculata	390a	260a	42a	34abc	9b
Bare Fallow	300a	130a	81a	2d	0d
Cajanus cajan	380a	180a	26a	4d	0d
Digitaria ciliaris	570a	200a	73a	13bcd	3c
Echinochloa colona	190a	320a	140a	24abcd	6bc
Alysicarpus vaginalis	350a	220a	71a	42abc	0.2cd
V. radiata var. radiata	560a	100a	210a	33abc	2c
Macroptilium artropurpureum	460a	210a	350a	122ab	35a
M. lathyroides	1040a	490a	94a	47abc	54a
Lablab purpureus	840a	660a	390a	82abc	9b
Psophocarpus palustris	270a	310a	170a	220a	43a
P <	NS	NS	NS	0.05	0.01

1. Values within the same column followed by the same letter do not differ significantly at the 5% level of probability (Duncans Multiple Range Test).

Grain and dry matter (DM) yield of maize in 1987

Grain and dry matter (DM) yields of maize in 1987 were greatest in treatments sown to M. lathyroides, M. artropurpureum, and P. palustris, and lowest in treatments sown to C. cajan and bare fallow in 1986 (Table 6). Moderately high yields were also obtained from maize crops which were preceded by L. purpureus and E. colona. Grain and DM yields were related primarily to soil matric potential at depths of 0.30m and 0.60m during tasselling (39-46 DAP) and late vegetative growth (20-30 DAP), respectively, thus:

Grain yield: $Y = 1.98\ e^{-0.23\ \Psi 30\ +\ 8.01 \times 10^{-2} \Psi 60}$, $R = 0.84^{***}$, $n = 48$;

DM yield: $DM = 16.05 - 1.52\ \ln \Psi_{30} - 1.97\ \ln \Psi_{60}$, $R = 0.92^{***}$, $n = 48$;

where Y is grain yield (Mg ha^{-1}), DM is dry matter yield (Mg ha^{-1}), Ψ_{30} and Ψ_{60} are mean soil matric potentials (- kPa) at depths of 0.30 and 0.60m, respectively, during tasselling (grain yield) and late vegetative growth (DM yield).

CONCLUSIONS

In relation to maize and cowpea, sowing of M. artropurpureum and M. lathyroides resulted in reduction of topsoil loss, increases in soil OM, C and C/N, exchangeable K, infiltration rate, soil matric potential and proportion of macropores ($r > 14.3 \mu m$), and decreases in soil temperature and proportion of micropores ($r < 2 \mu m$). These changes resulted in large increases in subsoil root growth, grain and DM yield of the following maize crop. Significant improvements in soil properties, and maize root growth and yield increases also occurred with P. palustris, L. purpureus and E. colona. Where either a bare fallow or C. cajan preceded a maize crop, soil degradation and, consequently, large yield decreases occurred. Soil ameliorative ability of cover

Table 6. Effect of preceding cover crop on oven-dry grain and dry matter (DM) yield of maize in 1987[1].

Preceding cover crop	Grain yield ($Mg\ ha^{-1}$)	DM yield ($Mg\ ha^{-1}$)
Zea mays	0.2 e	1.1 fg
Vigna unguiculata	0.2 e	1.6 ef
Bare fallow	6.7×10^{-6} f	0.2 g
Cajanus cajan	1.0×10^{-3} f	0.6 fg
Digitaria ciliaris	0.7 de	2.4 cde
Echinochloa colona	1.1 c	3.3 bc
Alysicarpus vaginalis	0.4 e	1.7 ef
V. radiata var. *radiata*	0.5 de	2.0 de
Macroptilium artropurpureum	2.2 a	4.3 ab
M. lathyroides	2.4 a	5.0 a
Lablab purpureus	0.8 d	3.2 bc
Psophocarpus palustris	1.5 b	3.9 b
P <	0.01	0.01

1. Values within the same column followed by the same letter do not differ significantly at the 5% level of probability (Duncan's Multiple Range Test).

crop was primarily related to rapidity of formation of ground cover and subsoil root density. Among the cover crops studied, M. lathyroides and M. artropurpureum were therefore, the most appropriate for the Sudan savannah of Burkina Faso.

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FIGURE CAPTIONS

Fig. 1. Seasonal variation of cover crop ground cover during 1986. Zea mays -—△— ; Digitaria ciliaris ----▲----; Echinochloa colona ---△---; Lablab purpureus —■— ; Macroptilium artropurpureum ---□----; M. lathyroides ----■----; Psophocarpus palustris —□— Cajanus cajan—o— ; Alysicarpus vaginalis---o--- Vigna unguiculata —▲— ; V. radiata---●--- Bare fallow—●—

Fig. 2. Effect of preceding cover crop on soil temperature at a depth of 30-mm at 24, 25, and 26 days after planting (DAP) in 1987. Symbols as in Fig. 1.

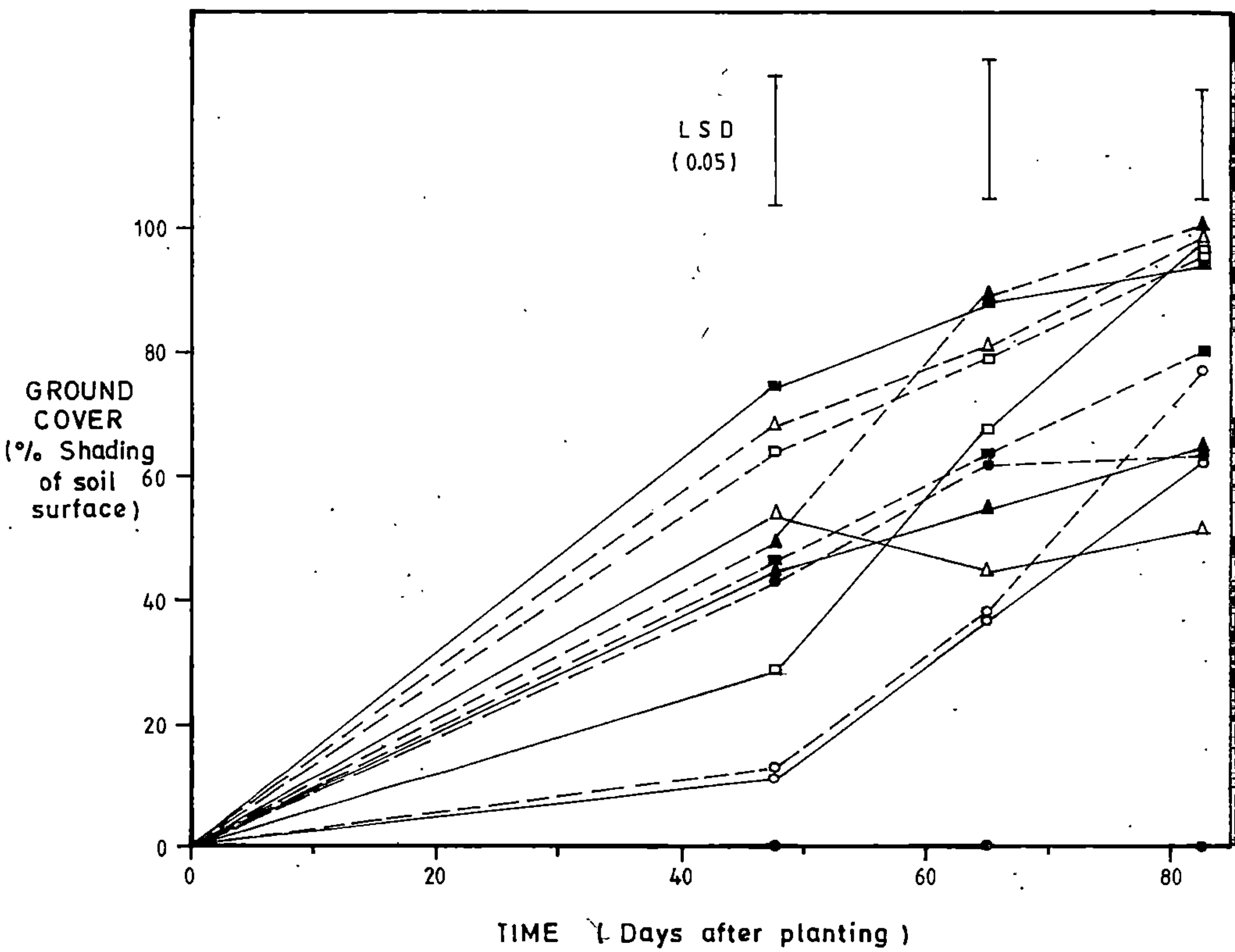
Fig. 3. Effect of preceding cover crop on soil temperature at a depth of 30-mm at 45 and 70 DAP in 1987. Symbols as in Fig. I.

Fig. 4. Effect of preceding cover crop on apparent pore size distribution at a depth of 0.30m. r = pore radius; Zm - Zea mays; Dc - Digitaria ciliaris; Ec - Echinolochloa colona; Lp - Lablab purpureus; Ma - Macroptilium artropurpureum; Ml - M. Lathyroides; Av - Alysicarpus vaginalis; Cc - Cajanus cajan; Vu - Vigna unguiculata Vr - Vigna radiata; B - bare fallow.

Fig. 5. Effect of preceding cover crop on apparent pore size distribution at a depth of 0.60m. Symbols as in Fig. 4.

Fig. 6. Effect of preceding cover crop on seasonal variation of soil matric potential at a depth of 0.30m during 1987. Symbols as in Fig. 1.

Fig. 7. Effect of preceding cover crop on seasonal variation of soil matric potential at a depth of 0.60m during 1987. Symbols as in Fig. 1.



LSD
(0.05)
100
80
60
40
20
0
GROUND
COVER
(% Shading
of soil
surface)
0
20
40
60
80
TIME (Days after planting)

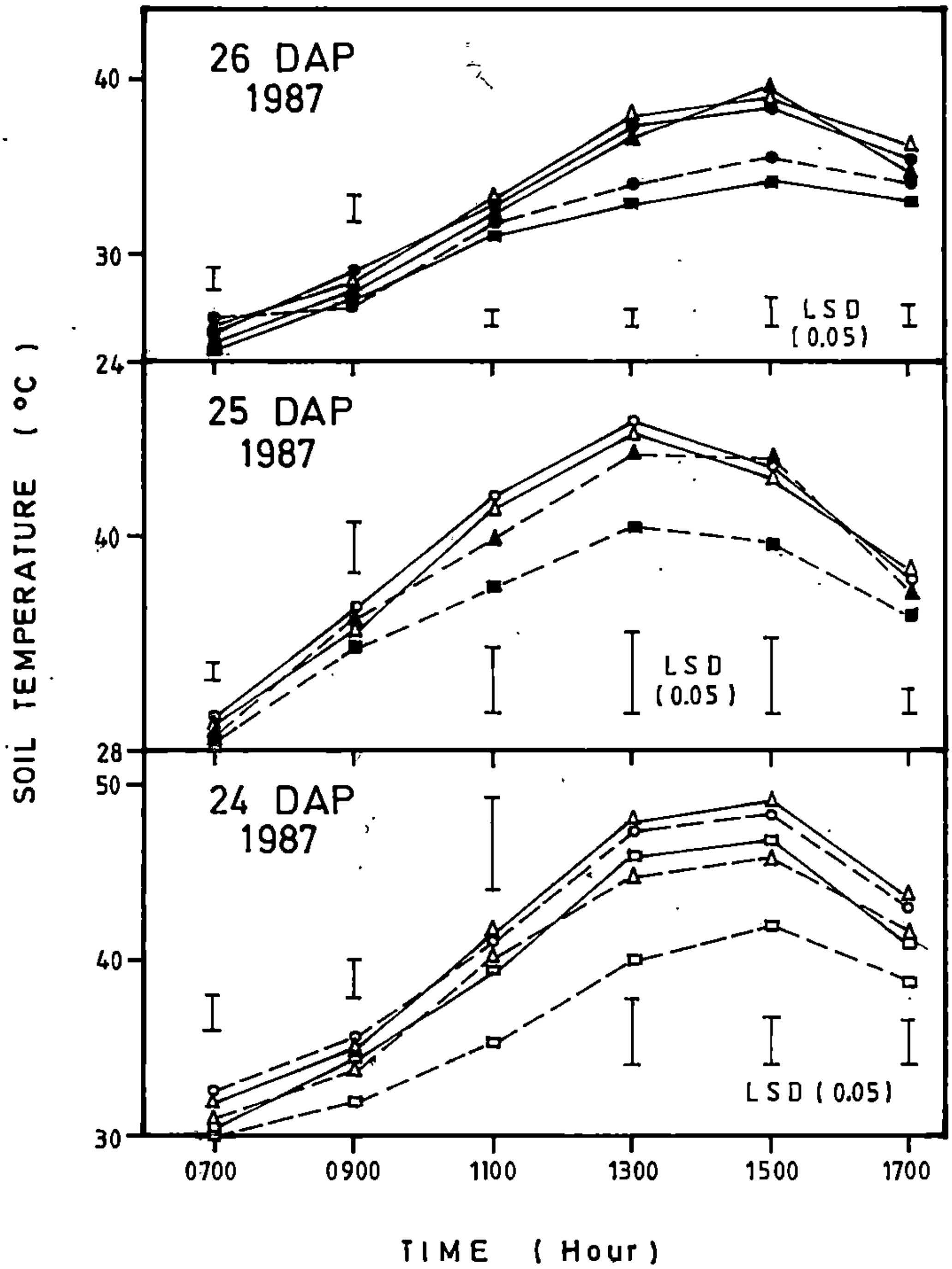
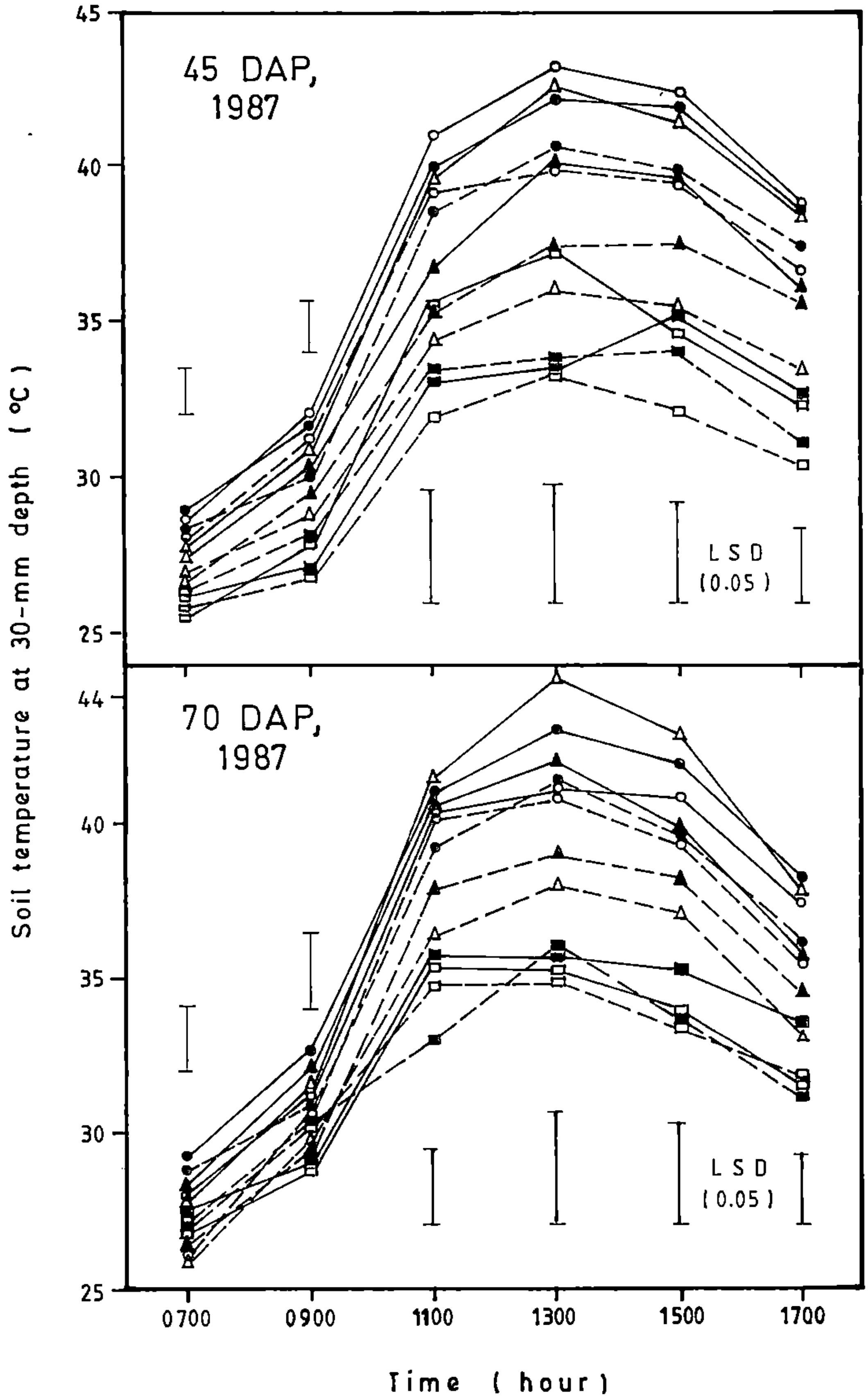
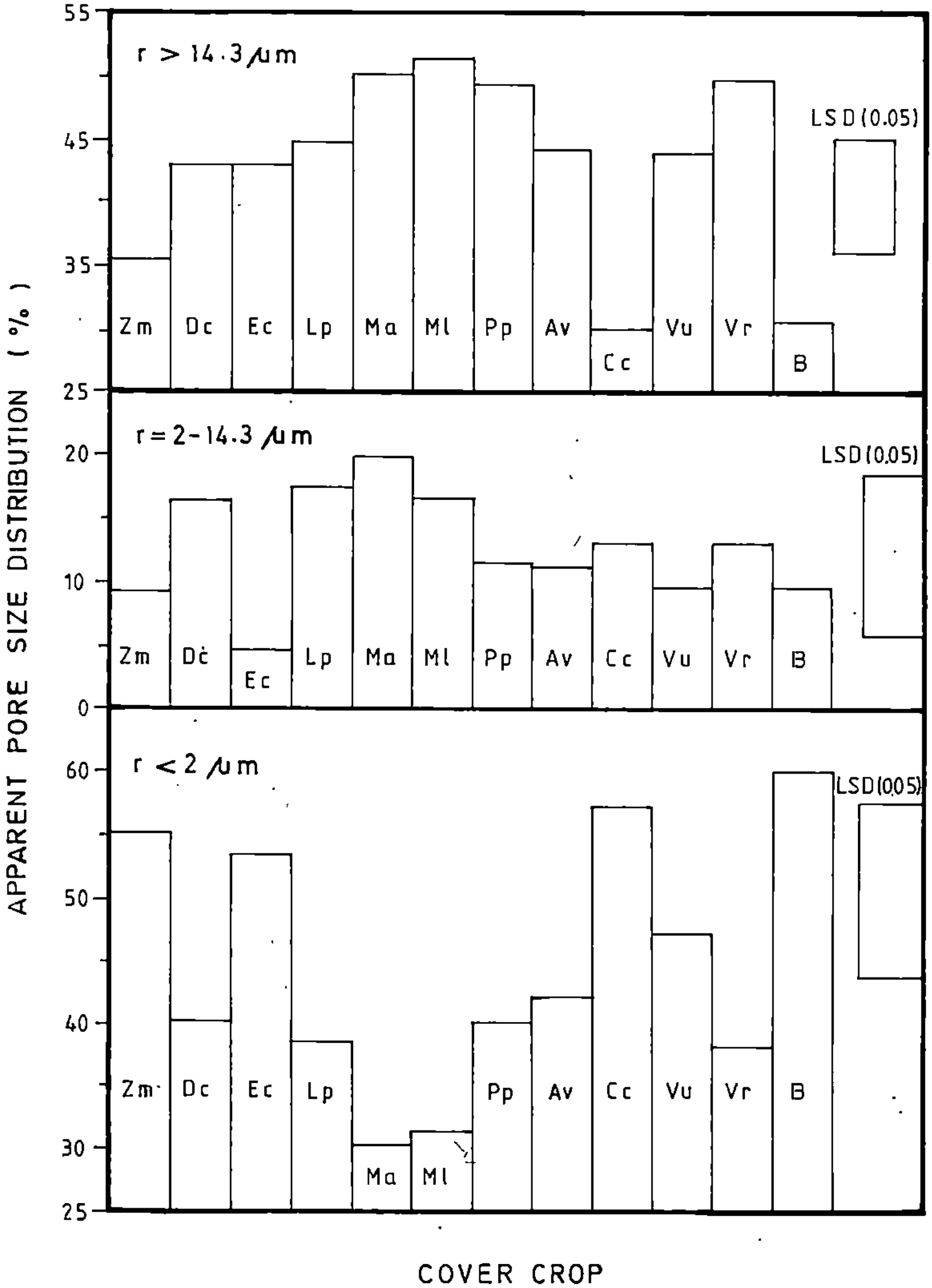

26 DAP
1987
25 DAP
1987
24 DAP
1987
SOIL TEMPERATURE (°C)
TIME (Hour)
0700
0900
1100
1300
1500
1700
LSD (0.05)
LSD (0.05)
LSD (0.05)

Fig.2


45 DAP,
1987
70 DAP,
1987
LSD
(0.05)
LSD
(0.05)
Soil temperature at 30-mm depth (°C)
Time (hour)
45
40
35
30
25
44
40
35
30
25
0700
0900
1100
1300
1500
1700



APPARENT PORE SIZE DISTRIBUTION (%)
r > 14.3 µm
r = 2-14.3 µm
r < 2 µm
LSD (0.05)
Zm
Dc
Ec
Lp
Ma
Ml
Pp
Av
Cc
Vu
Vr
B
55
45
35
25
20
10
0
60
50
40
30
COVER CROP

Г 4

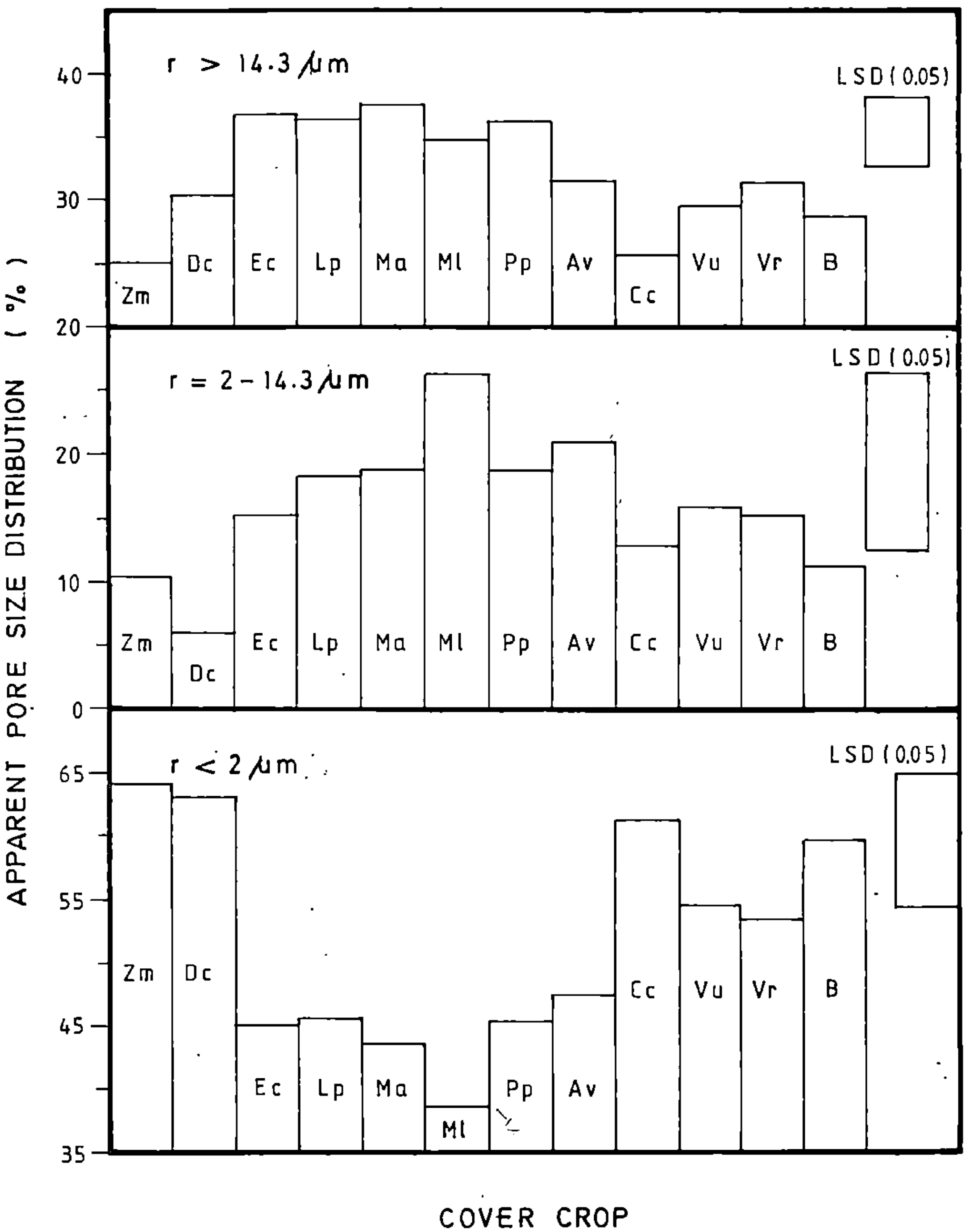
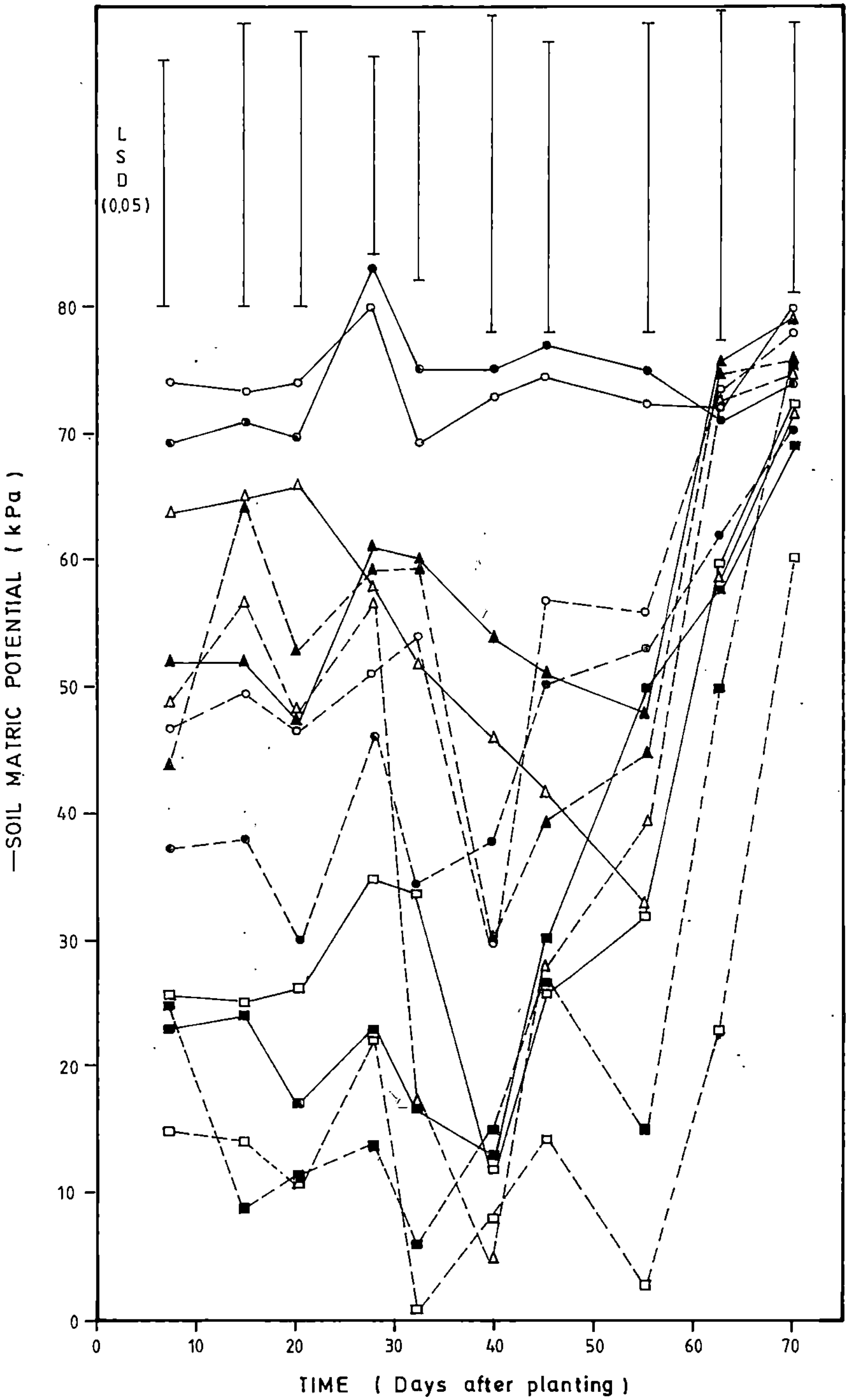
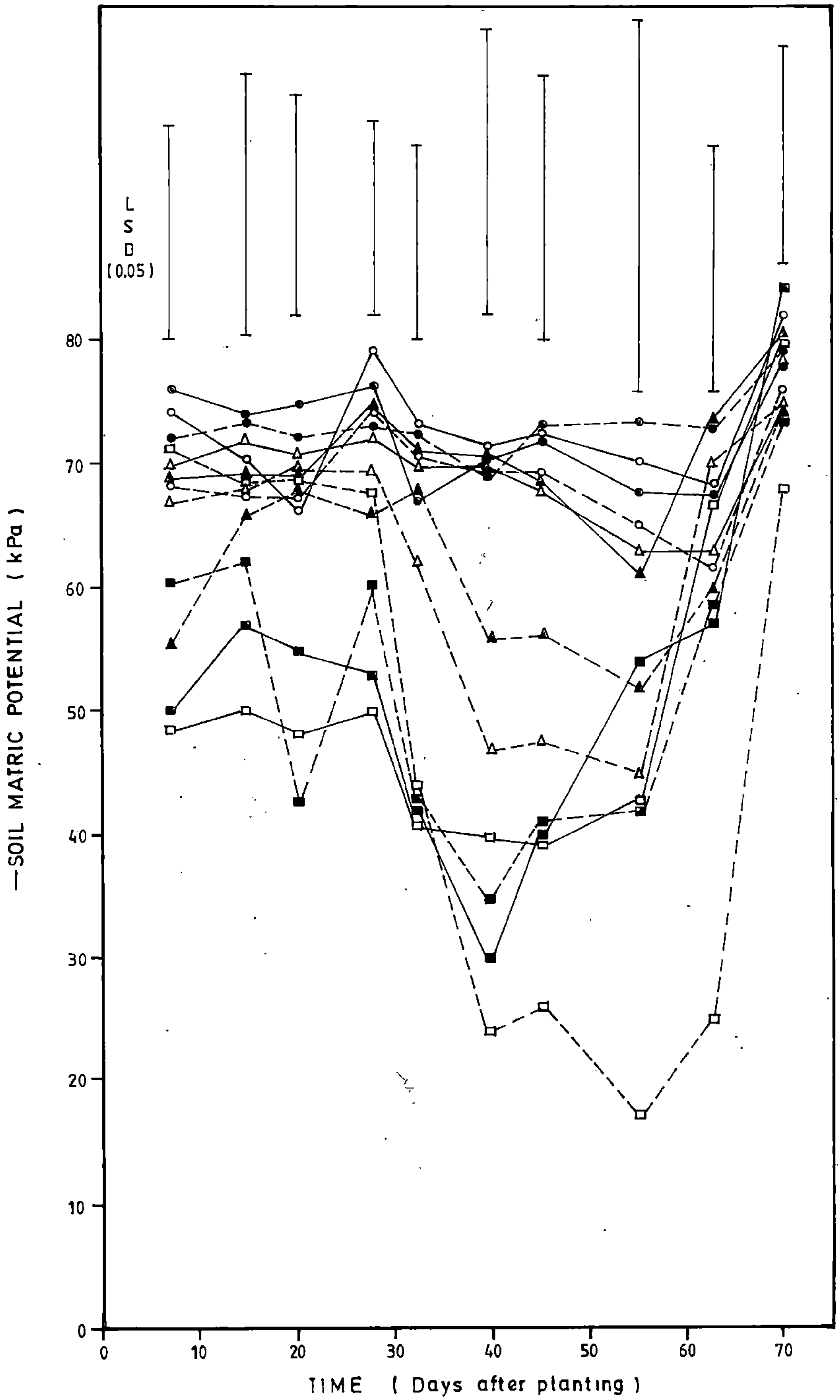

r > 14.3 µm
LSD (0.05)
40
30
20
Zm
Dc
Ec
Lp
Ma
Ml
Pp
Av
Cc
Vu
Vr
B
r = 2 - 14.3 µm
LSD (0.05)
20
10
0
r < 2 µm
LSD (0.05)
65
55
45
35
APPARENT PORE SIZE DISTRIBUTION (%)
COVER CROP

Fig. 5



L
S
D
(0.05)
80
70
60
50
40
30
20
10
0
—SOIL MATRIC POTENTIAL (kPa)
0
10
20
30
40
50
60
70
TIME (Days after planting)



L
S
D
(0.05)
—SOIL MATRIC POTENTIAL (kPa)
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
TIME (Days after planting)

1986

Effect of Cover Crop on Soil Physical and Chemical Properties of an Alfisol in the Sudan Savannah of Burkina Faso.

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AU-SAFGRAD