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KABULI CHICKPEA AS A WINTER-SOWN CROP IN NORTHERN SYRIA

MOISTURE RELATIONS AND CROP PRODUCTIVITY

By
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(ICARDA)

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SUMMARY

In the Mediterranean region, chickpeas are traditionally spring-sown since humid winter conditions encourage the development of *Aschochyta* blight which often causes complete crop failure. Lines resistant to this blight have been selected at ICARDA and thus winter planting has become feasible. The best selection, ILC 482, was sown in both winter and spring at three locations in northern Syria with contrasting precipitation patterns. Crop growth and soil moisture analyses were undertaken on all treatments, and relevant meteorological data were collected at each location. At all locations maximum green area and dry-matter production of the winter-sown crop was nearly double that of the spring sowing. Large differences were also observed between sites, with green area and dry-matter production decreasing with precipitation. Depth of profile recharge, amount of extractable moisture and crop evapotranspiration also decreased with precipitation, but only small differences in these moisture variables were observed between winter and spring sowing. Duration of green area production, as determined by the onset of rapid leaf senescence, was closely related to the fraction of extractable moisture in the soil profile, rapid senescence occurring in all treatments when extractable moisture fell below 40 % of its maximum value.

Differences in the maximum rates of green area production are discussed both in relation to the depth of profile recharge, hence the depth of rooting and moisture extraction and to the ambient evaporative demand. The differences observed in green area and dry-matter production were clearly reflected in final seed yield. The components of yield, number of pods, percentage of empty pods and seed size are related to the variations in moisture stress experienced by the crop.

Running title: Moisture relations and productivity of chickpea

INTRODUCTION

The climate of the Mediterranean basin is favourable for the production of Kabuli chickpea (*Cicer arietinum*). Thus, in this region it is an important and extensively grown spring planted crop. In 1976, 67,000 ha of chickpeas were planted in Syria as a spring-sown crop giving an average yield close to 0.75 t/ha (Arar, Sarraf & Tamimi, 1982). This poor yield can be partially attributed to the practice of spring planting which results in a short growing season of around 100 days. For the majority of this period crop growth is dependent on residual moisture supply and is subject to increasingly severe heat and drought stress as the season progresses. Saxena (1979) has stated that, though winter planting of chickpeas would not be seriously inhibited by cold considerations at low elevation, farmers generally retain a spring planting practice to avoid the incidence and damaging effects of *Aschochyta* blight.

Thus, a winter planting policy has only recently become feasible following the selection of lines at ICARDA, Aleppo that are more resistant to this blight. Initial agronomic studies on the season of planting have shown a considerable yield increase in favour of winter planting. Hawtin & Singh (1982) have reported that yields of the best winter planted line ILC 482 exceeded the local spring planted landrace by an average of 113 % in widespread on-farm trials. Average yields of ILC 482 as a winter planted crop from 18 locations in Syria was 1.8 t/ha.

The experiment reported in this paper was carried out to examine the effects of physical environmental factors on the growth and productivity of ILC 482. Winter and spring season plantings are compared at three locations spanning the considerable range in mean rainfall existing in northern Syria (600-200 mm precipitation per year).

MATERIALS AND METHODS

The experimental sites were located in Aleppo province at Jindiress (36°23'N 36°41'E), Tel Hadya (35°55'N 36°55'E) and Brida (35°55'N 37°10'E).

Soil types range from a Chromic Vertisol at Jindiress, through to a Vertic (calcic) Luvisol at Tel Hadya to a Calcic Xerosol at Brida. All soils were greater than 2 m deep and highly calcareous (pH $>$ 8.0). Full profile descriptions are given by Cooper et al. (1981).

In the winter season planting, five replications of ILC 482 (5 x 10 m) were sown by hand in mid November 1980 at a rate designed to achieve a stand density of 300 000 plants/ha. All plots received 60 kg/ha of P_2O_5 trickled into the trenches and a rhizobium slurry was applied. Insect damage by

podboring larvae (Heliothis spp.) was controlled by two sprayings of Thiodan in the reproductive phase. Weed control was maintained by handweeding. The spring season sowing was done in the 1st week of March 1981 and was in all other respects handled similarly to the winter sowing.

Harvesting was done by hand between early and mid June. Destructive samples of five plants were taken weekly from all replication, treatment and site combinations to enable a detailed growth analysis to be carried out. Green area indices were measured, including all parts of the crop capable of photosynthetic activity, with a photo-electric area meter (Hayashi Denkoh AAM7). Estimates of the area under the curves describing the relationship between green area index and time were made from measurements of scale drawings with the area machine.

Throughout the season soil profile moisture status was monitored at all sites and treatments using the neutron probe technique. Meteorological variables were measured daily on site and included total incoming radiant energy, air temperature, pan evaporation (class A) and precipitation. Evapotranspiration (E_t) for given time periods was determined according to the equation:

$$E_t = \Delta m + P - R - D$$

where, Δm is the change in total moisture stored in 0-180 cm soil profile in the period considered.

P is the recorded precipitation.

R is the soil surface run-off.

D is the drainage below 180 cm depth.

In this study, where all trial sites were flat, run-off (R) was not observed and drainage (D) below 180 cm did not occur. R and D were therefore ignored in calculating E_t.

RESULTS AND DISCUSSIONS

Climatic trends in the 1980-1 growth season

Figure 1 shows weekly precipitation and mean air temperature variations in the 1980-1 growth season. The start of the rainy season was approximately 5 weeks later than normal. As a result germination occurred at the cooler temperatures associated with mid-December, and though emergence was slow, stand density was good. The distribution of precipitation was generally favourable but rain was received later in the season than usual. Seasonal precipitation totals (see Table 2) were within 25 mm of the 20 year long-term seasonal means which are as follows: Jindiress 479 mm/year, Tel Hadya 342 mm/year and Brida 278 mm/year. Frost was not a significant factor at any of the experimental sites but typically low air temperatures were experienced for the first 3 months of the growth season. From late March onwards the rate of temperature increase was high, particularly in April and by harvest in mid June had reached super-optimal temperatures. Pan evaporation followed similar trends to temperature (see Fig. 6). In general the 1980-1 season could be regarded as a highly typical example of Meditterranean lowland climatic conditions.

Seasonal changes in soil moisture status

Soil moisture recharge and discharge patterns for the winter-sown chickpea at the three locations are presented in Fig. 2(a-f), and the seasonal variation in the total crop extractable moisture in the 0-180 cm profile for both winter and spring sown chickpea is given in Fig. 3. Crop extractable moisture is

defined as the difference between the maximum moisture content observed in a given soil depth interval and that at maturity.

During the cool winter months recharge of the soil profile occurred at all three locations. Maximum values of extractable moisture under winter-sown chickpea of 16.7, 9.9 and 6.9 cm at Jindiress, Tel Hadya and Brida were recorded on 5, 31 and 3 March 1981 respectively (see Fig. 3). Following this period of profile recharge, as the water requirements of the winter crop increased and rainfall decreased, rapid profile discharge occurred at all three locations and continued until crop maturity. A similar pattern of profile recharge occurred under the spring-sown crop, but owing to the later development of the crop canopy (Fig. 4), large amounts of extractable moisture persisted in the soil profile, and the onset of the period of rapid profile discharge was delayed until 8, 12 and 2 April at Jindiress, Tel Hadya and Brida.

Depth of moisture extraction by chickpea

In traditional chickpea growing areas in Syria, the chickpea crop usually follows wheat in a three course rotation of wheat-grain legume (lentil or chickpea) - summer crop (melon, cotton or sesame). At Jindiress and Tel Hadya the trial was planted within this rotation, but at Brida the land was fallowed in the previous season. At harvest of the preceeding wheat crop (May-June), by definition, the extractable moisture in the soil profile is zero with respect to wheat, and during the summer months further slow loss of soil moisture occurs by upward movement and surface evaporation. Studies at Tel Hadya have shown that such upward movement of moisture under fallow land during the summer months can occur from as deep as 105 cm, and this will be exacerbated in soils where deep

cracking occurs. Thus during the next rainy season it would seem likely that only soil depth intervals which become recharged by current rainfall would contain moisture which is available for uptake by the chickpea crop.

Reference to Fig. 2(a-f) clearly shows that the winter-sown chickpea only extracted moisture from depth intervals which had become recharged during the current season. However, at Jindiress, it was found that even though the winter-sown crop did not extract moisture from below the depth of profile recharge, it did extract moisture from within the depth interval 60-105 cm to a lower level than that observed at the start of the season, suggesting that chickpea may have a greater ability to extract moisture than wheat. The fact that this was not the case at Tel Hadya probably reflects the generally poorer growth of the chickpea crop at this location. In addition, other studies (Cooper et al. 1981) have shown that the extractable moisture under a cereal crop is increased by improved crop nutrition (N and P) and thus the extent to which a cereal crop leaves available moisture for a subsequent chickpea crop will depend on the relative vigour of the two crops. It is interesting to note that at Brida where the chickpea crop followed a fallow there was some additional moisture stored in the fallow from the preceeding season which was available to the crop. In Fig. 2 (b, d, f) the dotted line represents the moisture status at the start of the season, and thus the shaded area represents available moisture stored from the preceeding season.

At the two driest sites, Tel Hadya and Brida, the depth of profile recharge did not extend beyond 75-90 cm under both the winter and spring sown crop, and thus the depth of moisture extraction was restricted to this depth for both plantings. At these two sites there appeared to be little difference between

the root distribution of winter and spring-sown crops as reflected by extractable moisture, and this is illustrated by the data in Table 1 where the extractable moisture for discrete depth intervals is presented for the three locations. The differences between sites reflect the different soil moisture characteristics.

In contrast to the two driest sites, there were differences in the depth of soil profile recharge under winter and spring chickpea at Jindiress, and these are illustrated in Fig. 5 which shows the temporal distribution of moisture within discrete depth intervals. Here it can be seen that under winter-sown chickpea recharge in any given horizon reached a maximum value, but due to the established root system and the rapidly developing crop canopy, the recharge pattern reverted to discharge from early March onwards. This uptake of moisture by the crop reduced re-distribution of moisture by slow drainage into deeper horizons. In contrast, under spring-sown chickpeas where the crop canopy and root system had not developed to the same extent, depth intervals above 1 m became recharged and maintained high soil moisture contents for several months before discharge occurred in April. Under these conditions, greater moisture re-distribution by slow drainage occurred, and recharge was observed to occur as deep as 165-180 cm as compared with only 135-150 cm under the winter-sown crop.

It has been previously shown that under conditions of continuous profile discharge, careful examination of the temporal distribution of moisture within discrete depth intervals can be a useful tool in distinguishing between moisture loss from a horizon by slow drainage and crop uptake. Attention is paid to the period when the crop matures. A clear discontinuity in the slope of the

line at this time indicates that root uptake of moisture has ceased (see all depth intervals to 120 cm under spring-sown chickpea in Fig. 5), but no sharp change in the slope at maturity indicates continuing slow drainage loss (see depth intervals 120-180 in Fig. 5). The maximum depths at which this clear discontinuity occurs is marked with arrows, and it is apparent that the winter-sown crop has extracted moisture from as deep as 130-150 cm depth compared with only 105-120 cm depth under the spring sown crop. This suggests that in wetter areas, where root development is not so restricted by the depth of the recharge front, the winter-sown crop will develop a deeper rooting system than a spring-sown crop.

However, the extractable moisture data presented in Table 1 show that although the winter sown chickpea roots deeper, there was no evidence of increased water extraction at depths down to 105 cm. Thus the deeper root development of winter-sown chickpea at Jindiress only increased the total extractable moisture available to the crop to a small extent.

Evapotranspiration

Accumulated evapotranspiration data (E_t), class A pan evaporation (E_o) and rainfall data for all three locations are presented for selected dates in Table 2. Seasonal variation in daily E_o and E_t rates at the three locations are calculated and presented in Fig. 6. Total evapotranspiration between germination of the winter crop and maturity (95 % crop yellowing) is calculated.

Prior to planting in March moisture loss from the spring-sown plots was entirely due to evaporation from bare soil surfaces (E_s) and it can be seen that at this time there was no difference between E_s and the accumulated E_t of winter-sown crops at any location. (Table 2 and Fig. 6). This similarity of E_t of winter planted crops during the winter months compared with evaporation from a bare soil surface has been noted for other crops of the region (e.g. wheat, barley, lentils, faba beans. Cooper et al. 1981). During the winter, when crop leaf areas are small, and the soil surface is frequently re-wetted, E_s is the dominant component of E_t, and it is only in spring, when crop leaf areas increase rapidly and rainfall frequency decreases that measurable differences in E_t and E_s occur. This is an important point when comparing winter and spring-sown chickpeas since all root and shoot growth during winter is thus effectively 'free' in terms of moisture use.

During late March and April, as E_o values increased, the winter-sown crop, with its rapidly developing green area index (Fig. 4), transpired moisture at a greater rate than the spring-sown crop reaching maximum values of 5.0, 4.2 and 2.5 mm/day at Jindiress, Tel Hadya and Brida. However, in May, as the winter-sown crop approached maturity and its soil moisture reserves became depleted, the spring-sown crop, whose green area index was now fully developed transpired moisture at a greater rate. At maturity, the total accumulated E_t for both the winter and spring-sown crop were very similar at a given location.

It is interesting to note that in both winter and spring-sown chickpeas, maximum rates of evapotranspiration were attained well after the onset of the period of rapid decline in extractable soil moisture at all locations. Ritchie (1981) states that ... 'there is no reduction in the process (transpiration) being considered until the amount of extractable water in the entire root zone falls to some threshold value, following which the process is reduced in proportion to the extractable water'. This concept was tested using the E_t and extractable moisture data from all three locations. Time periods during profile depletion were examined for each crop at each location. Previous authors (Ritchie, Burnett & Henderson, 1972; Meyer & Green 1980) have used the ratio E_t/E_o to identify the time when water use begins to decline within crops which had achieved complete ground cover. However, in this study, owing to the very different and somewhat low green area indices (see Fig. 4), there was a wide range (0.95-0.27) of maximum E_t/E_o ratios attained by the crops between locations and planting dates. In order that all crops could be considered together, the E_t/E_o ratio for the periods examined were expressed as a fraction of the maximum value attained by each crop, and these values were related to the mean fraction of extractable moisture in the soil profile. The results are presented in Fig. 7. It is encouraging that, in spite of the very different soil types, soil moisture conditions, crop growth, rooting depths and dates of planting across the three locations, the concept holds true. The results suggest that, regardless of the above factors the E_t/E_o ratio will not be reduced by moisture stress below the maximum value attained by the crop until the fraction of extractable moisture in the root profile falls to 0.40. This threshhold value is somewhat higher than reported by Ritchie et al. (1972) and Meyer & Green (1980) who obtained their data from more frequent measurements in lysimeter studies udner crops which had achieved full ground cover.

Development of crop photosynthetic surface

Fourth order polynomial expressions were used to fit curves to the green area index (GAI) versus time data, and these curves are given in Fig. 4. The shape of the curves for the winter-sown crop, in particular its acutely peaked character, provide a clear visual integration of changes in environmental conditions which are typical of the Mediterranean region. During the cool wet winter months (Fig. 1) green area development rates were low, but during late March and early April, as temperatures rose, rapid rates of development occurred. Maximum GAI's were achieved at the end of April, approximately 140 days after germination, at all three sites. Thereafter there was pronounced leaf senescence and the GAI declined rapidly. A similar trend can be seen in the spring-sown crop, but it will be observed that early rates of green area development during the warm month of April were considerably higher than those of the winter-sown crop. Maximum GAI of the spring crop were achieved 26, 22 and 14 days later than for the winter-sown crop at Jindiress, Tel Hadya and Brida respectively.

It is clear that there were large differences in the maximum GAI's both between treatments and across sites. At all sites the winter-sown crop achieved nearly twice the GAI of the spring-sown crop, and this is reflected in the area under the curve (see Fig. 4). This marked effect results from both differences in the duration of rapid green area development (e.g. 38 v.32 and 34 v.20 days at Jindiress and Brida), and the maximum rates achieved (e.g. 0.15 v.0.08 and 0.05 v.0.03 $m^2/m^2/day$).

A careful comparison of the green area data in Fig. 4, and the extractable moisture data in Fig. 3 illustrates an important point. For both winter and spring-sown chickpea, the timing of the onset of rapid loss in green area coincides closely with the point at which the extractable moisture in the soil profile falls below 40 % of the maximum value. Ritchie et al. (1972) state that leaf senescence in determinate crops will occur at a certain stage of maturity regardless of the moisture status of the crop, whereas the leaves of indeterminate crops, such as chickpea, will not senesce during warm weather if the soil water supply is favourable. It would thus appear that the duration of maximum rates of green area development, as determined by the point at which rapid leaf senescence occurs, is controlled by the timing of the onset of moisture stress conditions. In view of the characteristic seasonal variation in extractable moisture (Fig. 3) and the relationship between extractable moisture and moisture stress (Fig. 7), it is apparent that a winter-sown chickpea crop will always have a greater potential for green area production at a given location.

In Fig. 4 it can also be seen that there are large differences in the maximum rates of green area production both between treatments and sites during periods of apparently adequate moisture supply. Why this should be the case is at present less well understood. However, it has been observed (e.g. Ritchie et al. 1972; Meyer & Green, 1980) that the process of leaf expansion is more sensitive to mild stress conditions than that of transpiration. This point is emphasized by Hsiao, O'Toole & Tomar (1979) who also illustrate that the depth of rooting is directly related to a crop's ability to maintain turgor pressure in growing cells during diurnal periods of high evaporative demand.

Reference to Fig. 2 indicates the large difference in rooting depth observed across sites, as reflected by the moisture uptake patterns during profile discharge. It thus seems probable that the deeper rooting at Jindiress allowed the crop to maintain turgor throughout the day to a greater extent than the more shallow rooting crops at Tel Hadya and Brida, resulting in the different green area production rates across the sites. However, we have already observed that there was little difference in rooting depth of winter and spring-sown chickpea at a given location (Table 1), and yet there were clear differences between the maximum rates of green area development. In this instance, the differences would seem more associated with the contrasting temperature and evaporative demand conditions experienced by the two sowing dates. Rapid rates of green area development of the winter-sown crops occurred during cooler weather with a lower evaporative demand than that experienced by the spring sown crops (see Figs 1 and 6). Thus, in spite of the similar rooting depth of the two sowing dates at a given location, the winter-sown crop would be likely to experience less diurnal stress and thus achieve greater green area development rates.

These hypotheses are based on crop growth, environmental and soil moisture measurements coupled with established physiological principles. However, although they satisfactorily explain the observed differences in crop behaviour, frequent diurnal measurements of the crop water status are required for confirmation. Such work is at present in progress.

Crop dry matter production

Best fit dry-matter production v. time curves (higher order polynomials) for all treatments are presented in Fig. 8. There were large differences, both between treatments and across sites, which strongly reflect those observed in green area development (see Fig. 4). Thus, further discussion on the interaction between environmental conditions and dry-matter production would merely be repetitive, as the direct relationship between green area development, radiant energy interception and dry-matter production has been firmly established in a wide range of crops and environments (Monteith, 1977; Littleton et al. 1979 a, b; Hughes & Keatinge, 1982).

Using E_t data from Table 2, and maximum dry matters from the curves in Fig. 8, water use efficiency (WUE) of total dry matter production was calculated. These are expressed in units of kg/ha/mm and are presented in Table 3. Winter-sown chickpea achieved far higher WUE values than the spring-sown crop. This results from two major factors. First, considerable moisture was lost by soil evaporation prior to germination of the spring-sown crop (see Table 2). Secondly, the proportion of E_t occurring as E_s is inversely related to the amount of radiant energy intercepted by the crop canopy. Thus, in the spring-sown crop, with its lower GAI and incomplete ground cover, a greater proportion of the E_t occurred as E_s. Such moisture loss is not associated with assimilate production, and would thus result in a lower WUE. This latter effect also accounts for the marked decrease in WUE within treatments between the wettest site, Jindiress, and the two drier sites, Tel Hadya and Brida.

Seed yield and yield components

Yields and components of yield are given in Table 3. Both treatment and site effects reflect the observed differences in vegetative growth. Winter planting resulted in a 123, 161 and 35 % increase in seed yield compared with spring planting at Jindiress, Tel Hadya and Brida. In addition there was a significant site effect, with large decreases in yield from the wettest to driest site.

Total grain yield of chickpea is the product of three major components: number of pods per plant, percentage of empty pods and seed weight. Number of pods per plant was generally higher in winter-planted chickpea, except at Brida where the number was low in both treatments. Number of pods per plant will be broadly related to the size of the pod-bearing structure, and this is illustrated by comparing the number of pods per plant and maximum dry-matter data in Table 3. Flower and immature pod abortion will modify this relationship and this is most evident in the winter planted chickpea at Brida.

Chickpeas characteristically produce a significant number of mature, but empty, pods. At the wettest location, Jindiress, there was no significant difference in this component of yield between winter and spring-sowings, but at the two driest sites there was a highly significant increase in empty pods in the spring-sown crop. Similarly, at the two driest locations seed weight was also significantly reduced in the later sowings. It would seem probable that the significant increase in both seed abortion (empty pods) and the decrease in final seed weight in the spring-sown crop at the two driest locations reflect the increasing severity of moisture stress effects on green area and assimilate production.

In areas of limited moisture supply, the success or failure of a new agronomic practice can be most usefully expressed in a manner which relates the amount of harvested yield produced per unit of moisture used. The WUE of seed production data are presented in Table 3. It is clear that winter-sowing has given a dramatic increase in WUE at Jindiress (117 %) and Tel Hadya (148 %), and a smaller increase (33 %) at Brida. In addition, as was observed in the discussion on the WUE of dry-matter production, WUE of seed production also declines at the drier sites.

CONCLUSION

In northern Syria spring-planted chickpeas are in general restricted to areas with a seasonal rainfall greater than 400 mm owing to their sensitivity to drought which we have highlighted in this paper. The adoption therefore of a cultivar with enhanced disease resistance and the consequent possibility of a winter-sowing habit has several important implications. First, if farmers are prepared to accept a somewhat enhanced agronomic risk from factors such as weed control and frost, winter-planting will result in considerably higher yields in traditional chickpea growing areas. Secondly, winter-planting would enable a large extension of the area under chickpea production into the 300-400 mm seasonal precipitation zone by taking advantage of moisture that is currently lost as soil evaporation in the winter season. Productivity in winter-sown crops grown in this zone would be expected to be reduced from potential levels by soil moisture stress and yet would remain highly competitive with the productivity associated with the traditional lentil crop. Thirdly, even in traditional barley gorwing areas (250-300 mm), in terms of protein production and farmer income, a winter-planted chickpea crop could provide a viable alternative to barley. However, in this region, the risk of crop

failure in dry years may prove to be unacceptable to the farmer. The development of earlier maturing disease-resistant chickpea lines for winter planting would certainly be one way to extend the area under chickpea production into drier regions by substantially reducing this risk.

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Table 1 Extractable soil moisture (cm) in discrete depth intervals under chickpeas at Jindiress, Tel Hadya and Brida

Depth	Jindiress		Tel Hadya		Brida	
	Winter sown	Spring sown	Winter sown	Spring sown	Winter sown	Spring sown
0- 15	2.56	2.82	2.87	3.00	2.41	2.83
15- 30	2.61	2.58	2.55	2.43	1.76	1.86
30- 45	2.58	2.57	2.40	2.32	1.42	1.41
45- 60	2.31	2.42	2.02	2.02	1.01	1.00
60- 75	2.16	2.23	0.94	0.89	0.40	0.34
75- 90	1.92	1.87	0.04	0.07	0.11	0.28
90-105	1.34	1.38	-	-	-	-
105-120	0.95	0.69	-	-	-	-
120-135	0.63	-	-	-	-	-
135-150	0.16	-	-	-	-	-
Total	17.21	16.56	10.82	10.73	7.11	7.72

Table 2

Accumulated water use (E_t) by spring and winter-planted chickpea at three locations in northern Syria (mm germination-maturity)

Jindiress

Date	2.i	22.i	4.ii	5.iii	22.iii	8.iv	26.iv	11.v	1.vi	14.vi	Maturity date	Total evapotranspiration germination → maturity
WS	46	94	104	139	165	221	302	377	424	428	22.v. 81	422
SS	48	93	107	145	163	204	231	294	384	413	14.vi.81	413
E_o	49	91	119	185	250	324	410	496	617	744	-	-
R*	120	237	274	338	359	401	413	456	456	456	-	-

Tel Hadya

Date	22.i	13.i	29.i	1.iii	31.iii	13.iv	30.iv	19.v	2.vi	11.vi	Maturity date	Total evapotranspiration germination → maturity
WS	18	52	74	108	153	173	244	299	311	311	25.v. 81	311
SS	16	52	71	109	144	154	194	251	290	300	8.vi.81	297
E_o	26	59	82	158	281	350	477	623	775	889	-	-
R*	70	158	189	247	298	305	325	351	357	357	-	-

* Rainfall accumulated from onset of season.

Table 2 (Conted.)

Accumulated water use (E_c) by spring and winter-planted chickpea at three locations in northern Syria (mm germination-maturity)

Brida

Date	31.xii	20.i	8.ii	3.iii	16.iii	2.iv	23.iv	7.v	21.v	9.vi	Maturity date	Total evapotranspiration germination → maturity
WS	15	34	56	77	106	143	195	226	250	257	22.v. 81	252
SS	14	37	58	82	102	130	162	207	236	249	5.vi.81	246
E_o	35	61	100	148	197	268	369	478	583	786	-	-
R*	86	115	125	174	184	223	232	274	277	277	-	-

* Rainfall accumulated from onset of season.

Table 3

Crop productivity, yield components and water use efficiency of winter and spring planted chickpeas at three locations in northern Syria*

Site/ Treatment	Maximum above ground dry-matter ≠ (t/ha)	Water use efficiency (kg/ha/mm)		Number of pods per plant	Empty pod (%)	100-seed weight (gm)	Seed yield (t/ha)
		Dry-matter	Seed				
Jindiress							
WS	7.88	18.7	10.0	72.6 (5.98)	17.2 (1.03)	24.3 (0.33)	4.20 (0.295)
SS	3.74	9.1	4.6	31.1 (1.01)	22.4 (2.21)	23.4 (0.52)	1.88 (0.081)
Tel Hadya							
WS	3.42	11.0	6.7	27.6 (0.59)	4.6 (1.09)	27.0 (0.37)	2.09 (0.022)
SS	1.84	6.2	2.7	17.1 (2.09)	17.5 (1.18)	23.2 (0.50)	0.80 (0.116)
Brida							
WS	2.72	10.8	4.0	13.7 (0.54)	6.7 (0.70)	28.1 (0.56)	1.00 (0.038)
SS	1.85	7.5	3.0	17.1 (0.67)	20.1 (4.73)	19.2 (0.58)	0.74 (0.049)
Site effect							
Jindiress	-	-	-	51.8 (7.48)	19.8 (1.44)	23.9 (0.33)	3.04 (0.411)
Tel Hadya	-	-	-	22.3 (2.03)	11.1 (2.08)	25.1 (0.70)	1.46 (0.226)
Brida	-	-	-	15.4 (0.69)	13.4 (3.18)	24.0 (1.40)	0.87 (0.050)
Treatment effect							
WS	-	-	-	37.9 (7.00)	9.5 (1.93)	26.4 (0.48)	2.43 (0.37)
SS	-	-	-	21.7 (1.91)	20.0 (1.74)	22.2 (0.51)	1.14 (0.15)

WS = Winter-sowing SS = Spring-sowing

≠ Estimated from best fit polynomial regression equations.

* Figures in parentheses are standard errors.

FIGURE LEGENDS

Fig. 1 Seasonal variation in precipitation and air temperature at three sites in northern Syria (a) Jindiress; (b) Tel Hadya; (c) Brida.

Fig. 2 Soil moisture recharge and discharge under winter-sown chickpea at three locations in northern Syria (a) and (b) Jindiress; (c) and (d) Tel Hadya; (e) and (f) Brida. Shaded areas represent moisture extracted to a lower level than that observed at the start of the season.

Fig. 3 Seasonal change in extractable moisture in 0-180 cm soil profile under winter (——) and spring-sown (---) chickpea at three locations in northern Syria (a) Jindiress; (b) Tel Hadya; (c) Brida.

Fig. 4 Canopy development in winter and spring-sown chickpeas at three locations in northern Syria (a) Jindiress; (b) Tel Hadya; (c) Brida. (Area under the curves is expressed as a percentage of the winter-sown treatment at Jindiress).

Fig. 5 Temporal distribution of moisture within discrete soil horizons under winter and spring-sown chickpea at Jindiress 1980-1 (a) winter-sown; (b) spring-sown.

Fig. 6 Seasonal variation in rate of pan evaporation, E_o (——) and evapotranspiration, E_t (---) under winter (WS) and spring-sown chickpea (SS) at three locations in northern Syria (a) Jindiress; (b) Tel Hadya; (c) Brida.

Fig. 7 The influence of extractable moisture on the relative value of the E_t/E_o ratio of winter and spring-sown chickpea at Jindiress (●), Tel Hadya (o) and Brida (X).

Fig. 8 Dry-matter production in winter (WS) and spring-sown (SS) chickpea at Jindiress (---), Tel Hadya (——) and Brida (.....).

Fig. 1

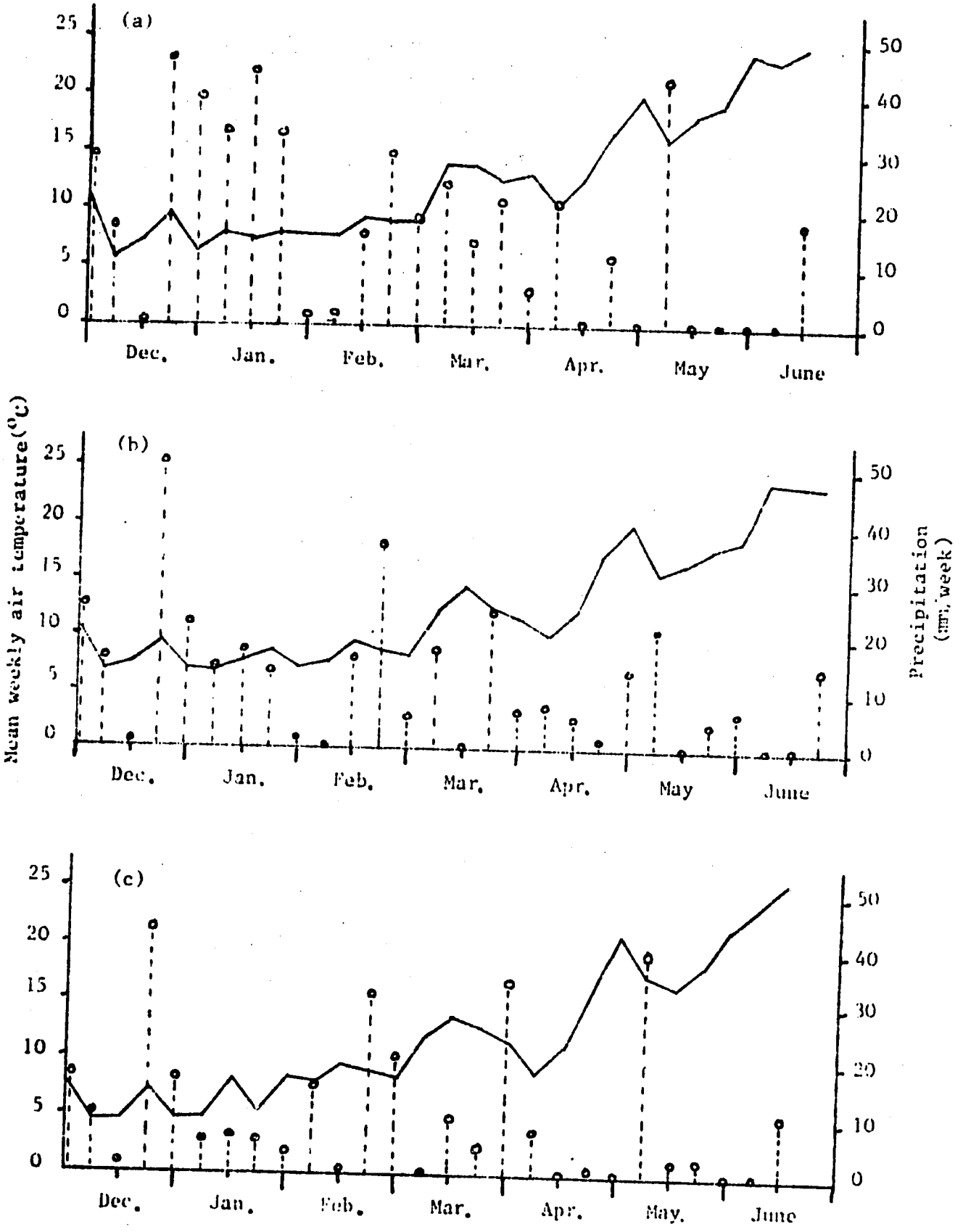

(a)
(b)
(c)
Mean weekly air temperature (°C)
Precipitation (mm/week)
0
5
10
15
20
25
0
10
20
30
40
50
Dec.
Jan.
Feb.
Mar.
Apr.
May
June

Fig. 1

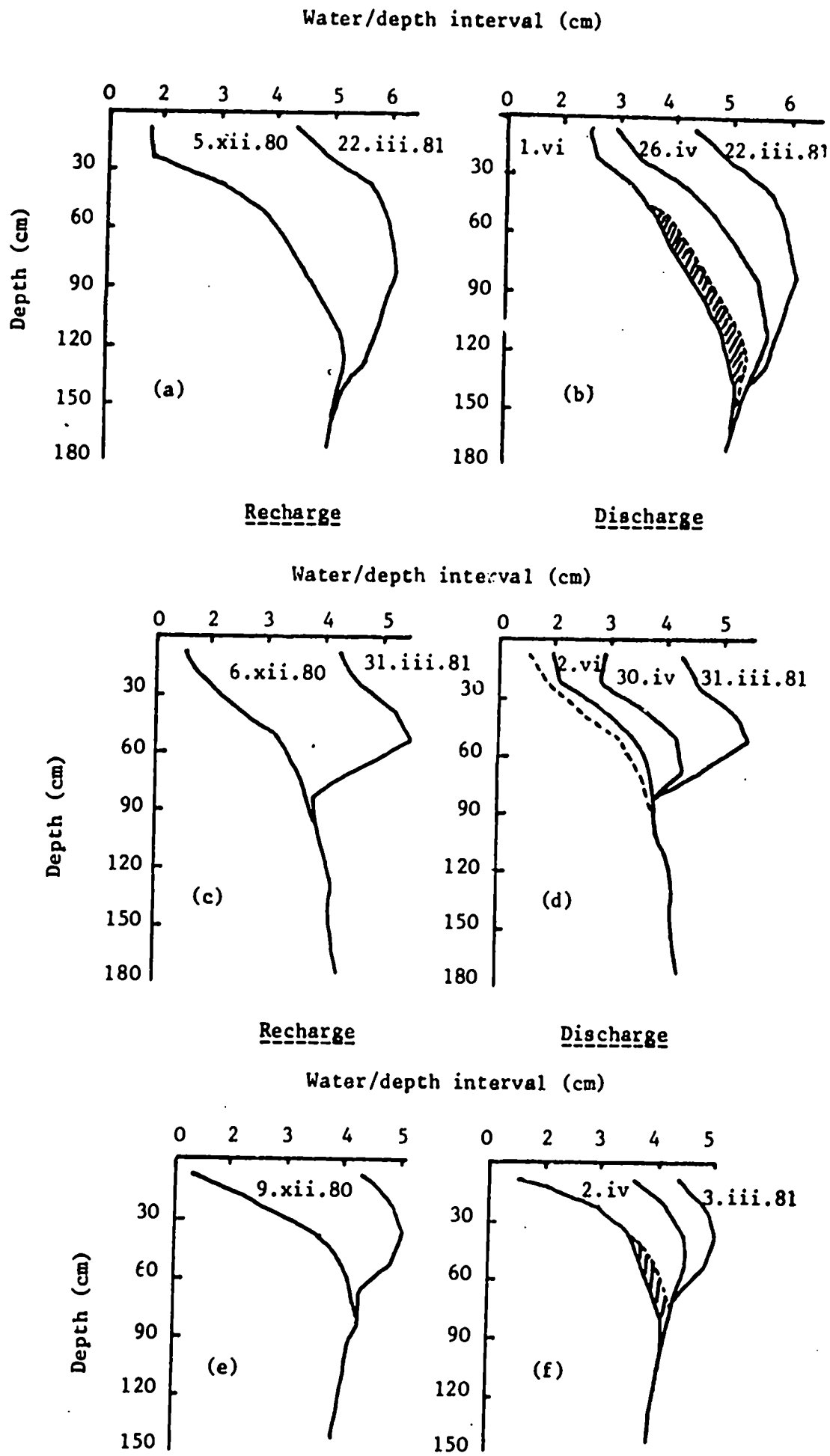

Recharge
Discharge
Water/depth interval (cm)
0 2 3 4 5 6
Depth (cm)
30 60 90 120 150 180
5.xii.80
22.iii.81
(a)
1.vi
26.iv
22.iii.81
(b)
Recharge
Discharge
Water/depth interval (cm)
0 2 3 4 5
6.xii.80
31.iii.81
(c)
2.vi
30.iv
31.iii.81
(d)
Recharge
Discharge
Water/depth interval (cm)
0 2 3 4 5
9.xii.80
(e)
2.iv
3.iii.81
(f)

Fig. 3

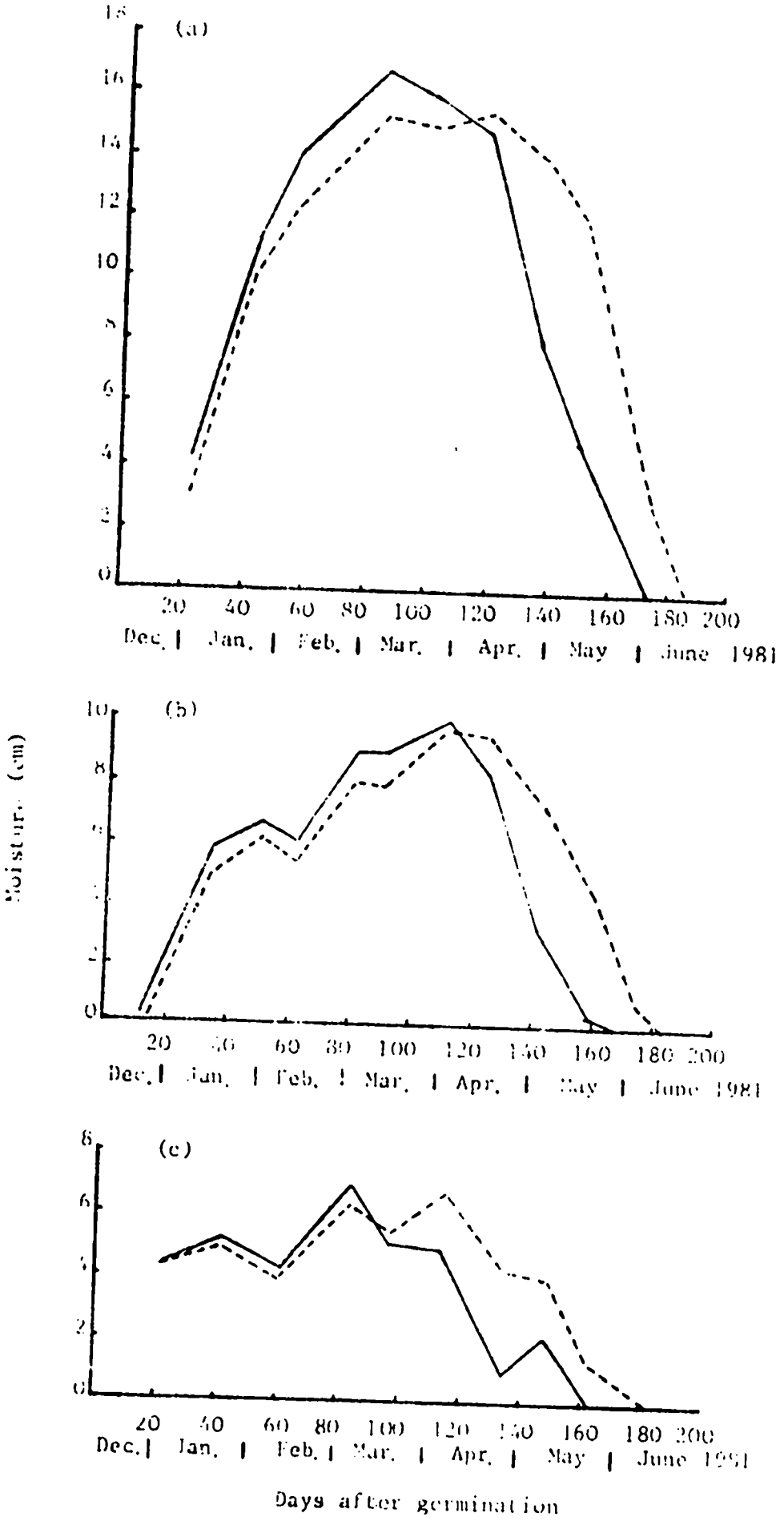
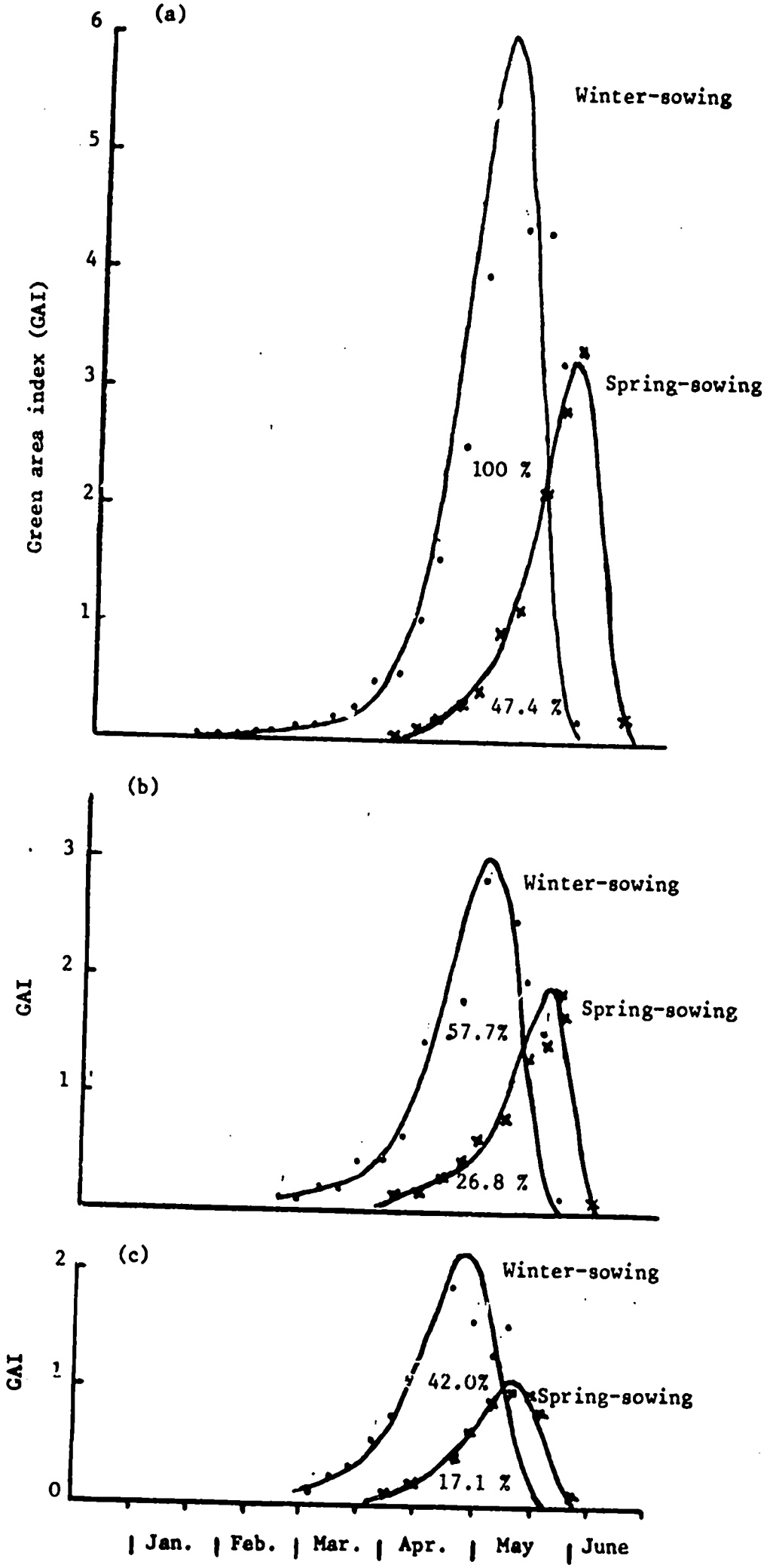

(a)
(b)
(c)
Moisture (cm)
Dec. | Jan. | Feb. | Mar. | Apr. | May | June 1981
Days after germination

Fig 4


(a)
Green area index (GAI)
6
5
4
3
2
1
Winter-sowing
Spring-sowing
100 %
47.4 %
(b)
GAI
3
2
1
Winter-sowing
Spring-sowing
57.7%
26.8 %
(c)
GAI
2
1
0
Winter-sowing
Spring-sowing
42.0%
17.1 %
Jan.
Feb.
Mar.
Apr.
May
June

28

Fig. 5

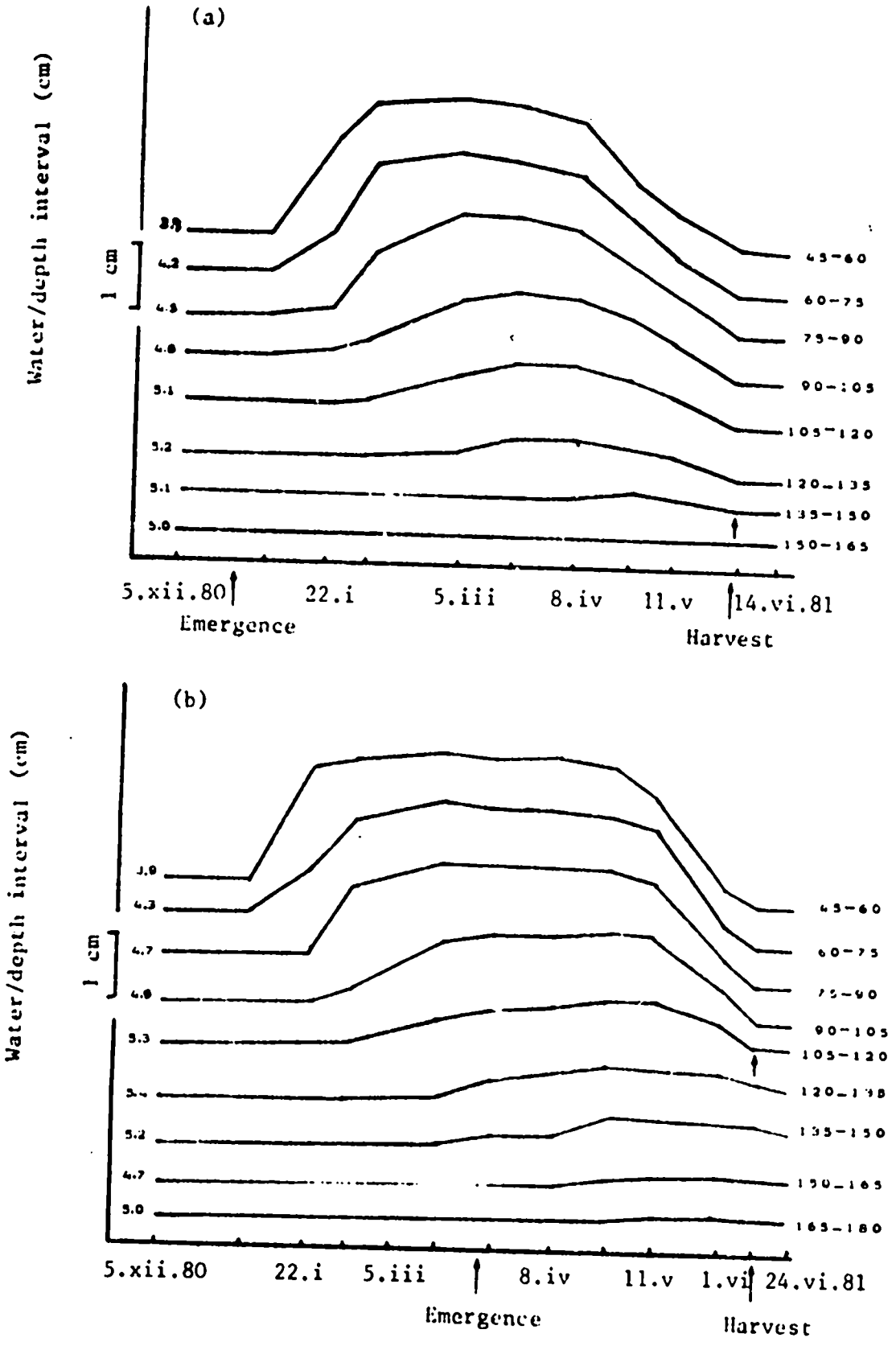

(a)
Water/depth interval (cm)
1 cm
45-60
60-75
75-90
90-105
105-120
120-135
135-150
150-165
5.xii.80
22.i
5.iii
8.iv
11.v
14.vi.81
Emergence
Harvest
(b)
Water/depth interval (cm)
1 cm
45-60
60-75
75-90
90-105
105-120
135-150
150-165
165-180
5.xii.80
22.i
5.iii
8.iv
11.v
1.vi
24.vi.81
Emergence
Harvest

Fig 6

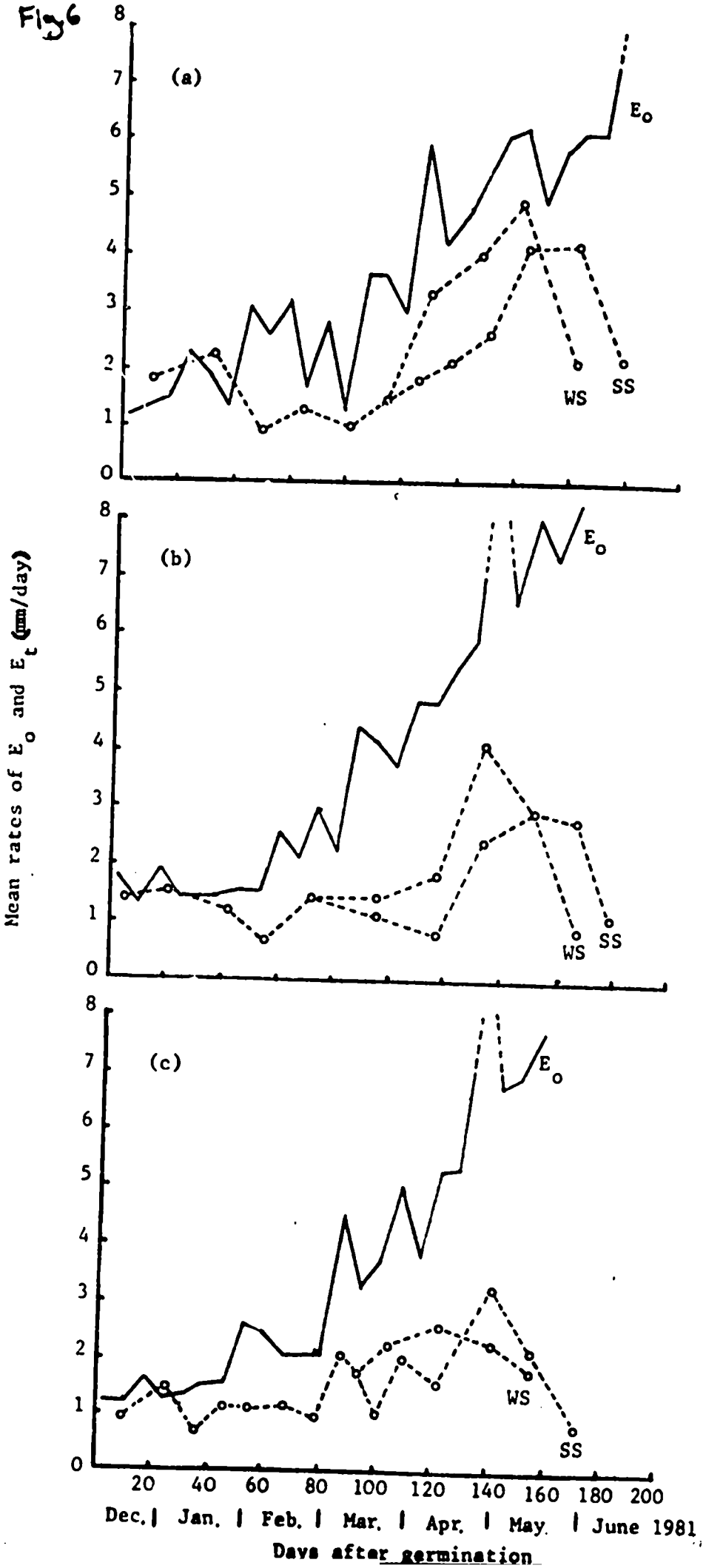

(a)
(b)
(c)
E_o
WS
SS
Mean rates of E_o and E_t (mm/day)
0
1
2
3
4
5
6
7
8
20
40
60
80
100
120
140
160
180
200
Dec. | Jan. | Feb. | Mar. | Apr. | May | June 1981
Days after germination

Fig.7

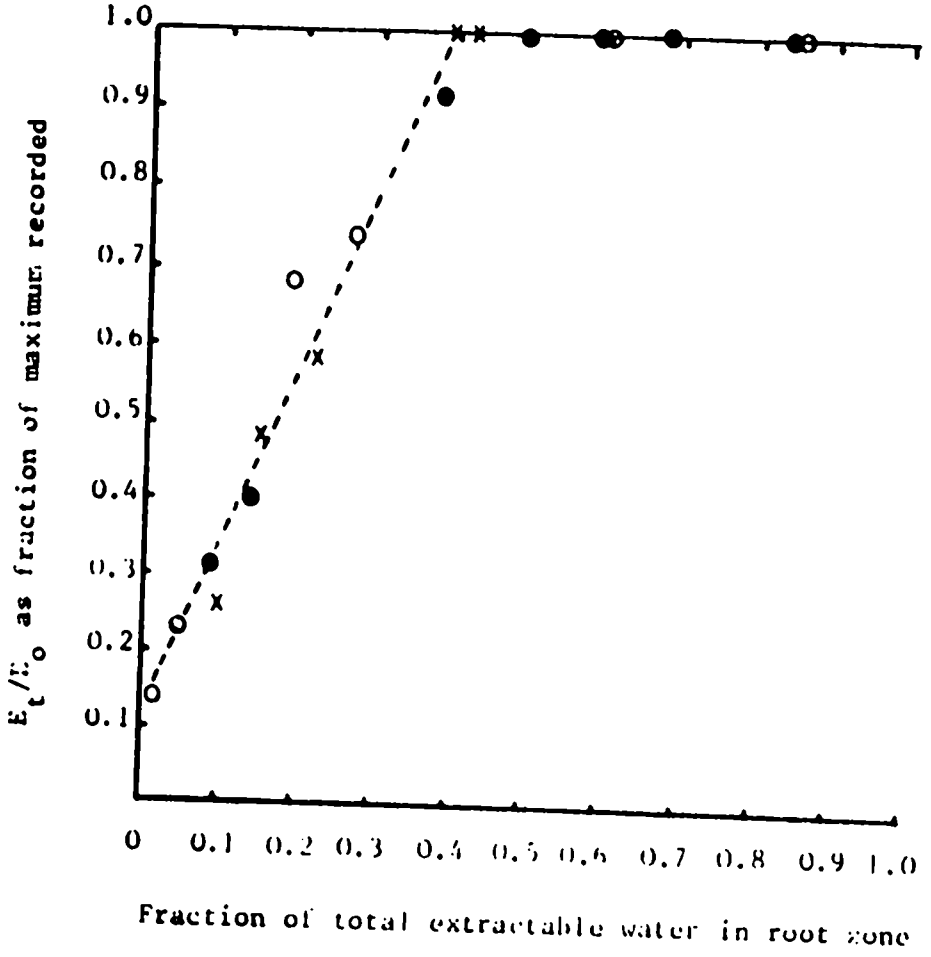
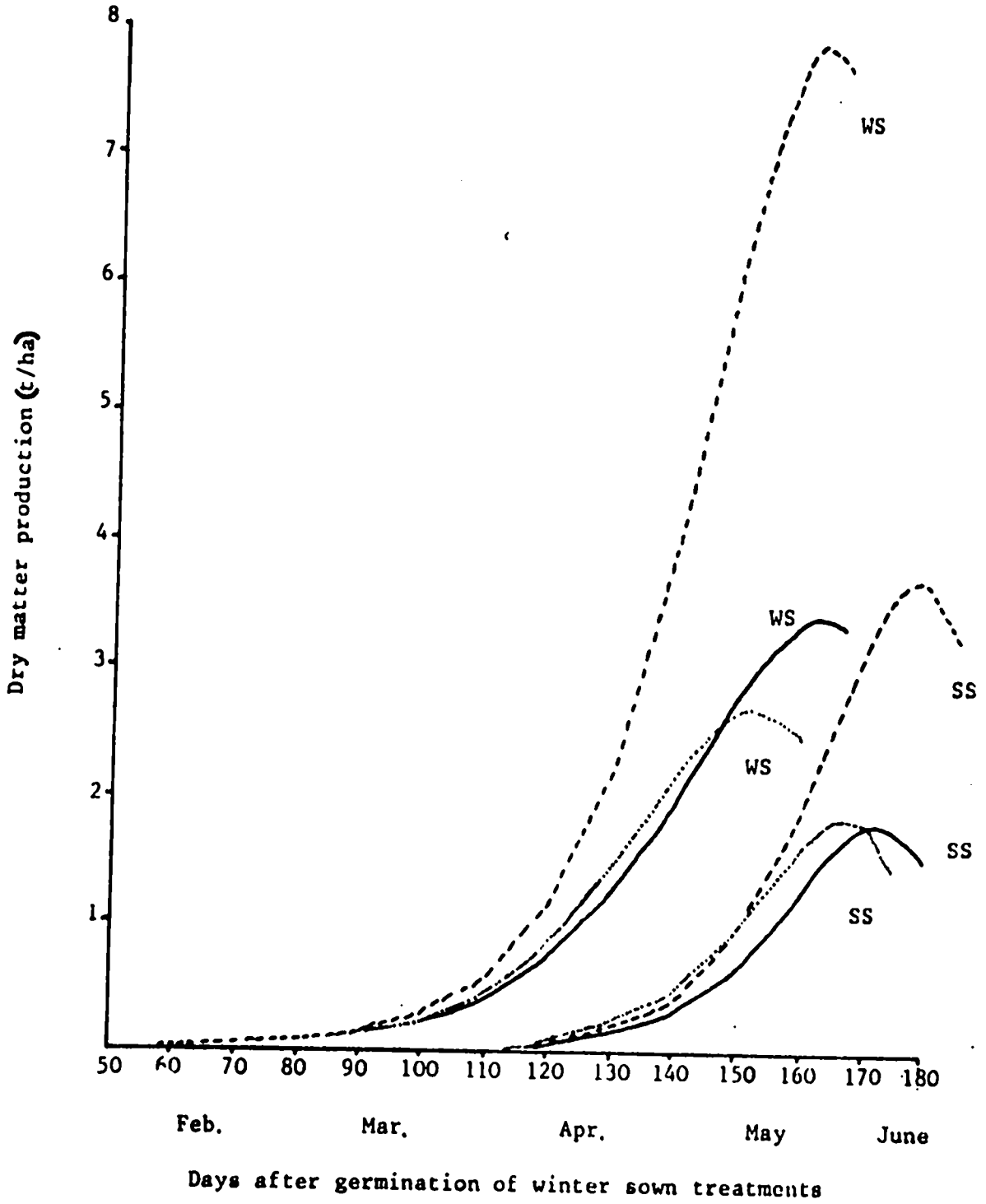

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
E_t/E_o as fraction of maximum recorded
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Fraction of total extractable water in root zone

Fig. 8


Dry matter production (t/ha)
8
7
6
5
4
3
2
1
WS
WS
WS
SS
SS
SS
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Feb.
Mar.
Apr.
May
June
Days after germination of winter sown treatments