TABLE I

Individual values of enzyme activity in groups of animals on Feb. 15 and Feb. 16 at the 16·00 hr time interval

Enzyme (units)	Enzyme activity							
	Feb. 15				Feb. 16			
NADH oxidase of erythrocyte membrane* (nmoles NADH. min^{-1}. mg protein^{-1})	3·2,	1·6,	1·1,		31·7,	31·7,	19·0,	
NADH oxidase of hepatic microsomes (nmoles O_2. min^{-1}. mg protein^{-1})	242,	124,	174,	212	213,	168,	206,	190
Tryptophan pyrrolase of hepatic cytosol (nmoles. hr^{-1}. mg protein^{-1})	14·1,	26·4,	12·0,	18·3	20·1,	18·2,	27·7,	12·2,
HMGCoA reductase of hepatic microsomes (pmoles mavalonate. min^{-1}. mg protein^{-1})	130,	214,	115,	210	115,	110,	71,	69

* *Only three samples were tested.*

Adaptation II and Influence of Drugs on Mitochondrial Metabolism, and the Junior Research Fellowship to S. V. from the Department of Atomic Energy are acknowledged.

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SORGHUM BASED CROPPING SYSTEMS TO MEET SHORTAGES OF PULSES AND EDIBLE OILSEEDS

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ABSTRACT

The shift from tall and late varieties of sorghum to early maturing hybrids has not only conferred greater levels of productivity and stability but has opened up opportunities for practice of new cropping systems in rainfed areas. Based on extensive experimentation, the opportunities for enhancing pulse and edible oilseed production on the existing areas of sorghum through practice of suitable inter- and sequence cropping systems have been analysed.

TRADITIONAL tropical dryland agriculture continues to be largely of the subsistence type. Tropical cultivars are generally tall and late (>150 days), the duration of the crop growing season being longer compared to the duration of rainy season. Subnormal rains or restricted duration of monsoon result in the reduction of yields or total crop failures (Rao *et al.*[3]). Traditional mixed cropping, practised over ages, has been predominantly a strategy of subsistence for farmers to alleviate total risk and to achieve some measure of security.

Genotype Alteration and Sole Crop Stability

Recent efforts at genotypic alterations involving corrections for duration, dry matter production and distribution and changes in growth rhythms have resulted in the development of a new set of sorghum cultivars with higher levels of performance and stability when grown as sole crops. They are less vulnerable to climatic fluctuations. Examination of comparative yield levels of locals and improved cultivars along with the corresponding coefficients of variation over several years reveals that locals are not only low yielding but also less stable in performance (Rao and Rana[4]). The productivity and stability of such altered sorghums over several years is reflected in Fig. 1.

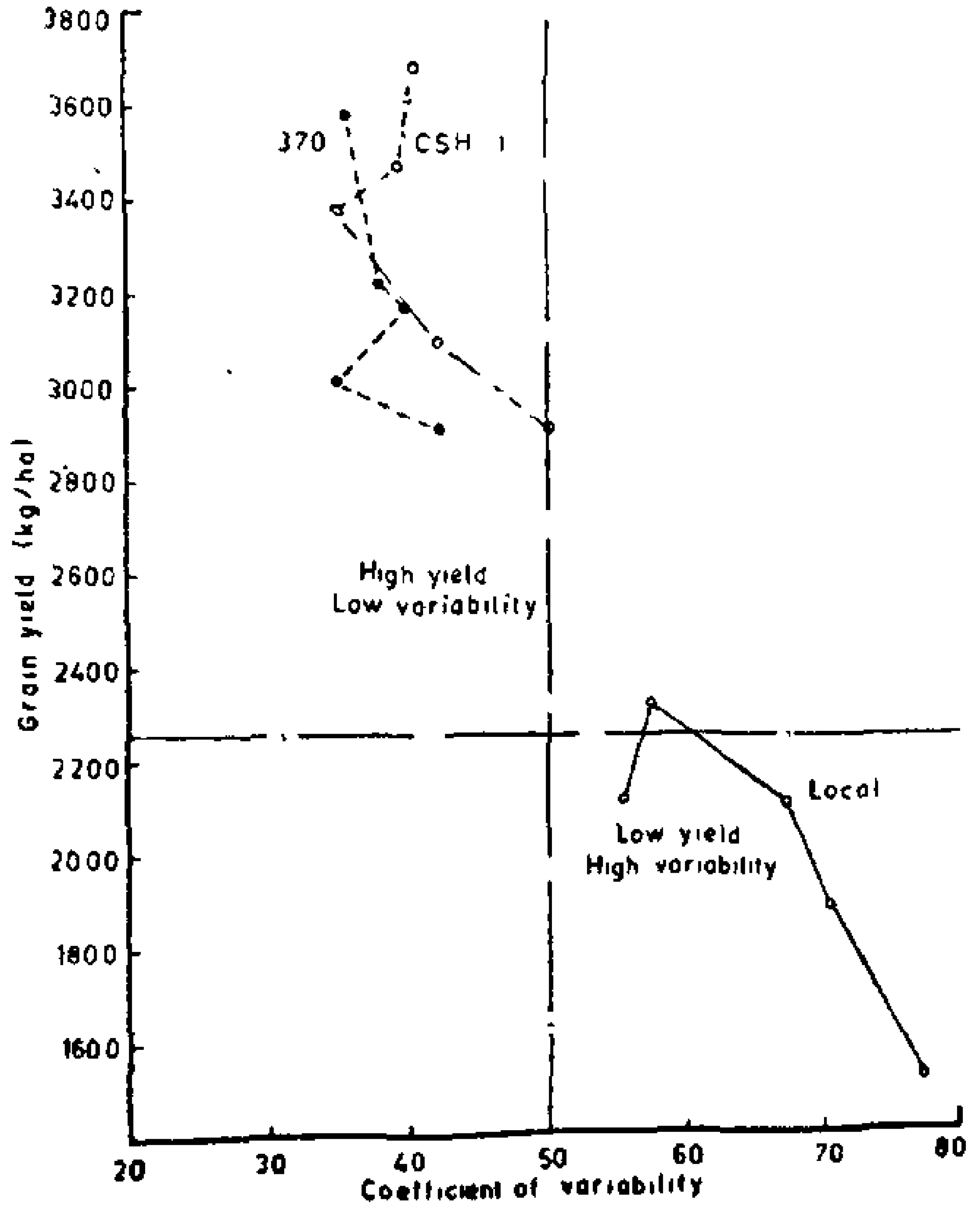

FIG. 1. Productivity and stability of local and improved cultivars of sorghum as sole crops.

Genotypic Basis for Alteration of Dryland Cropping Systems

The advent of newer genotypes with reduced duration, greater levels of productivity and stability of sole crops usher an emerging era of productive and stable dryland cropping systems involving scientific intercropping as well as sequence cropping. It is in this context that the sorghum based cropping systems could meet the shortages of pulses (grain legumes) and edible oilseeds.

Sorghums in India are essentially rainfed and are cultivated annually over an area of 17–18 million hectares primarily in the States of Maharashtra, Karnataka, Andhra Preadesh, Madhya Pradesh, Rajasthan, Gujarat, Tamil Nadu and the Bundelkhand region of Uttar Pradesh. The rainfall over this area ranges from 600–1200 mm received from the last week of June to mid-September or mid-October. The *kharif* sorghums constitute nearly 2/3 of the total area and the *rabi* the remaining 1/3. Most of the *kharif* area and the entire *rabi* constitutes retentive black soils; only parts of Tamil Nadu and Andhra Pradesh grow some sorghum in red soils.

The consumptive use of water for a 105-day hybrid sorghum during *kharif* is 368 mm and for a 130-day *rabi* variety 348 mm. Consumptive use of water for *mung* (65 days) is 207 mm, for soybean (110 days) 352 mm and *kharif* groundnut (110 days) 342 mm. These are for the Deccan region and should hold good for *Malwa* plateau and most other sorghum growing tracts (Kadam, Ramakrishna Rao and Varade[2]). This means, areas receiving over 750–800 mm of annual rainfall are suitable for growing more than one crop during a year even under rainfed conditions by using cultivars of appropriate duration. Areas which receive less than 700 mm of rainfall are more suited for practice of productive intercropping systems. Their productivity could even be higher if practised in better rainfall regions. That the maximum food production potential in different regions of India is much higher than what is being realised has been brought out by Sinha and Swaminathan[6].

Modern Intercropping Systems

The design and development of stable and productive intercropping systems takes into consideration, (1) the choice of crops and varieties based on inter- and intra-species competition, (2) genotype *x* density interactions and (3) alternate planting patterns so as to maintain the yields of the principal crop comparable to its sole crop yield and obtaining additional production of oilseed or pulse crops grown as intercrops (Rao, Rana and Tarhalkar[4]).

Data on sorghum based intercropping systems from the All-India Sorghum Project, IARI Regional Station, Hyderabad and the All-India Dryland Project (Choudhury[1]) over a seven-year period (1972–78), are analysed and presented in Table I. The sorghum yields in the intercropping system compare well to their respective sole crop yields at over 30 q/ha and the average yields of intercrops vary from 3–9 q/ha depending upon the crop. Approximately 95–97 % of the sole crop sorghum yield was realised in intercropping systems with groundnut/soybean, *mung* or pigeonpea. The yield levels of pulses and oilseeds

TABLE I

Production potential of oilseeds and pulses in sorghum based intercropping systems (Kharif 1972–78)

Intercrop	No. of experiments	(Avrage yield q/ha) Sorghum (sole crop)	Intercrop (sole crop)	Sorghum (in inter-cropping system)	Intercrop (in inter-cropping system)	Projected area million ha for 1 million ton production Minimum yield potential	Average yield potential	Maximum yield potential
Oilseed Crops								
Groundnut	57	33·6±2·7	10·4±1·4*	33·1±1·8	4·8±·5	2·60	2·08	1·73
Castor	20	36·7±4·3	20·2±1·5*	32·9±2·0	5·3±·8	2·78	1·90	1·44
Sunflower	10	33·6±5·4	16·1±3·8	21·7±3·2	3·4±·9	8·00	2·99	1·84
Pulse Crops								
Pigeonpea (*arhar*)	115	35·8±1·9	16·5±0·9	32·4±1·4	9·4±·4	1·16	1·07	1·00
Soybean	60	33·0±1·9	13·9±0·7	32·2±1·8	5·5±·3	2·08	1·82	1·61
Greengram (*mung*)	38	33·5±2·7	8·2±0·7	32·7±2·0	3·1±·3	3·90	3·25	2·78
Blackgram (*urid*)	30	40·9±3·0	9·5±0·7*	33·8±2·1	2·8±·3	4·58	3·55	2·90
Cowpea	21	43·5±4·4	8·2±0·4*	38·1±4·1	2·7±·5	5·75	3·67	2·69

* Data based on less number of experiments.

when grown as intercrops in various All-India trials are depicted in Figs. 2 and 3. Pigeonpea and soybean among pulses and groundnut, in the case of oilseeds, have larger number of trials with higher levels of yield. With castor, the total number of trials is rather low. Based on the maximum, minimum and average yields of intercrops realized during different years, projections have been made for additional production of pulses and edible oilseeds. At average yield levels, one million tons of an intercrop could be produced from 1·07 m ha for pigeonpea, 1·82 m ha, for soybean and 2·08 m ha for groundnut. From the overall performance (Fig. 4), pigeonpea (*arhar*) and soybean among pulses and groundnut among edible oils offer greater opportunities for additional production on the existing areas of *kharif* sorghum. They are more stable in intercropping systems and relatively more productive.

The advent of high yielding sorghum hybrids have turned farmers towards growing them as sole crops since they are more remunerative than traditional mixed cropping. The hybrid sorghum area, particularly in low rainfall areas, could practise more productive intercropping with pigeonpea or soybean. In such areas, the duration of pigeonpea should not be excessively longer as it would then become subject to moisture stress. Soybean is less susceptible to competition compared to traditional pulses like *mung* and may have an increasing scope in years to come. Groundnut yields are low in sorghum based intercropping systems, but the haulms enrich the value of the fodder and if practised over a million hectares the groundnut production during *kharif* could be substantial. In groundnut based systems, sorghum yields are not at all reduced.

Policy decisions could delineate areas for appropriate intercropping systems of sorghum and pulses or oilseeds to meet the shortages. The advantages of intercropping systems from the point of view of promoting soil fertility, possibly a non-polluting means of controlling pests and diseases and capitalizing on allelopathic effects, is also receiving increasing attention (Trenbath[7]).

Two Crop Sequences

Black soil areas receiving over 750–800 mm rainfall are assured single crop areas with new hybrids of sorghum and potential two-crop areas. Data on two crop sequences are presented in Table II. Safflower as an edible oil and chickpea (gram) as a pulse are the most potential crops that could follow a *kharif* hybrid sorghum. A crop like *mung* could precede a *rabi* sorghum in assured rainfall areas of Maharashtra, Karnataka and Andhra Pradesh. In the black soil areas, the land during *kharif* usually remains fallow. *Mung* under heavy rains is subject to virus diseases; *urid* is of longer duration though less susceptible. Development of virus resistant *mung* or *urid* comparable in duration to *mung* and perfection of their production technology during *kharif*

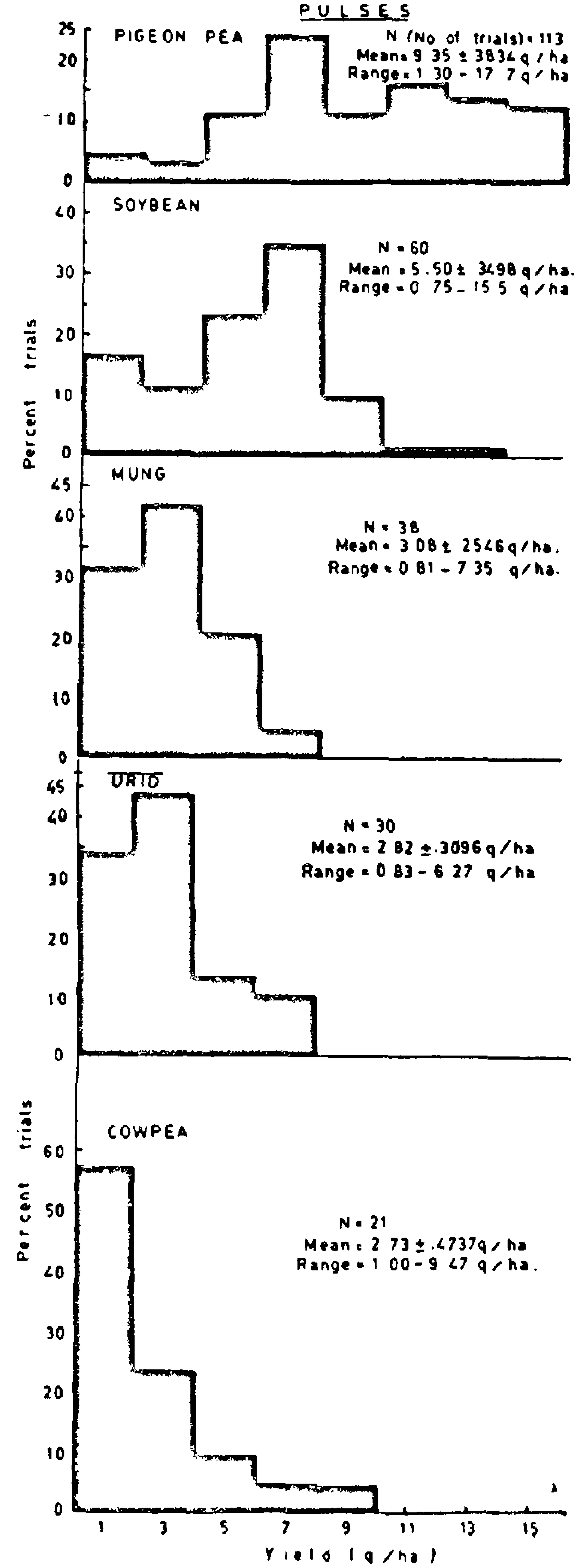

FIG. 2. Yield levels of intercrops in various trials from sorghum based intercropping systems—Pulses.

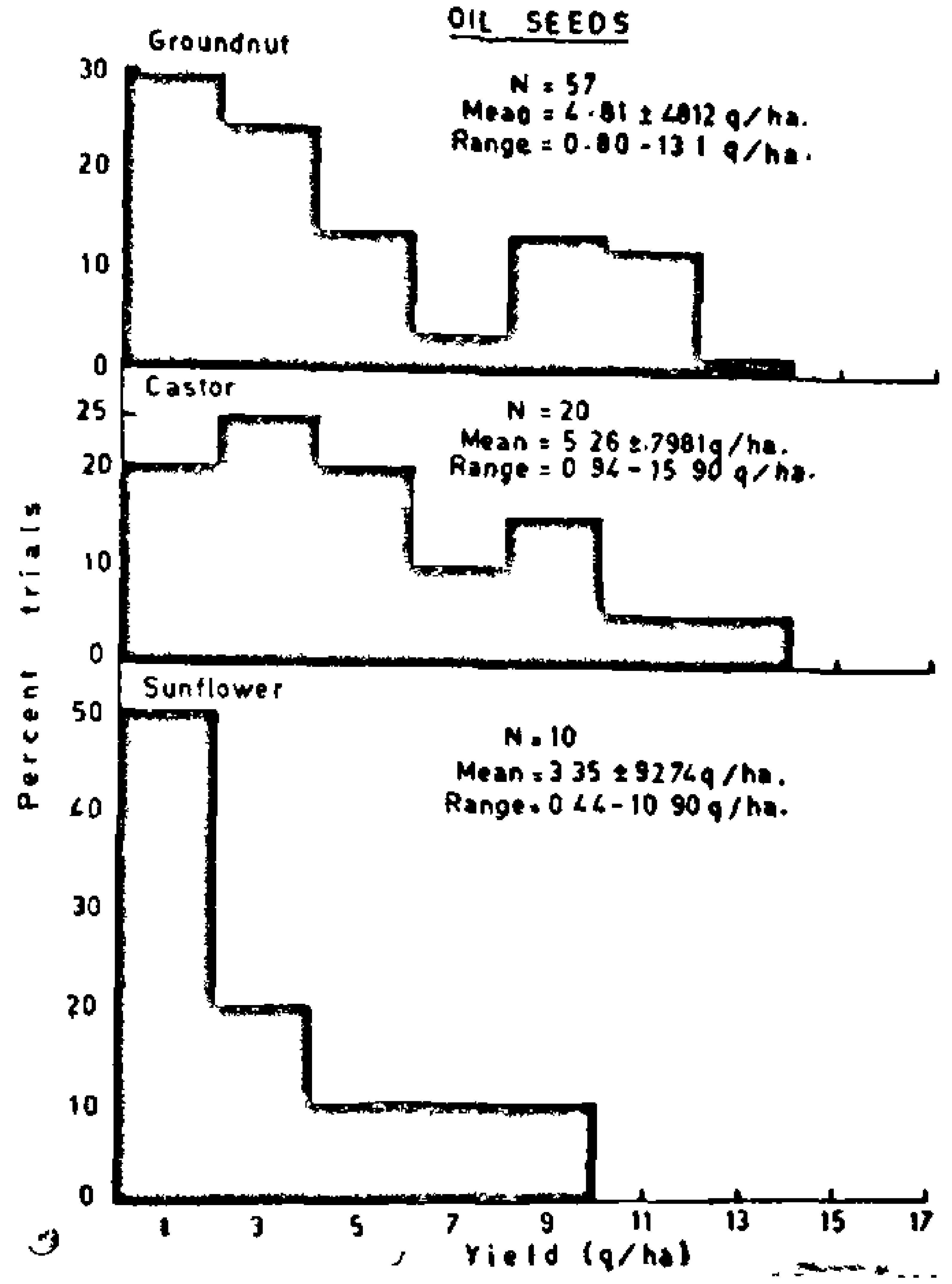

FIG. 3. Yield levels of intercrops in various trials from sorghum based intercropping systems—Oilseeds.

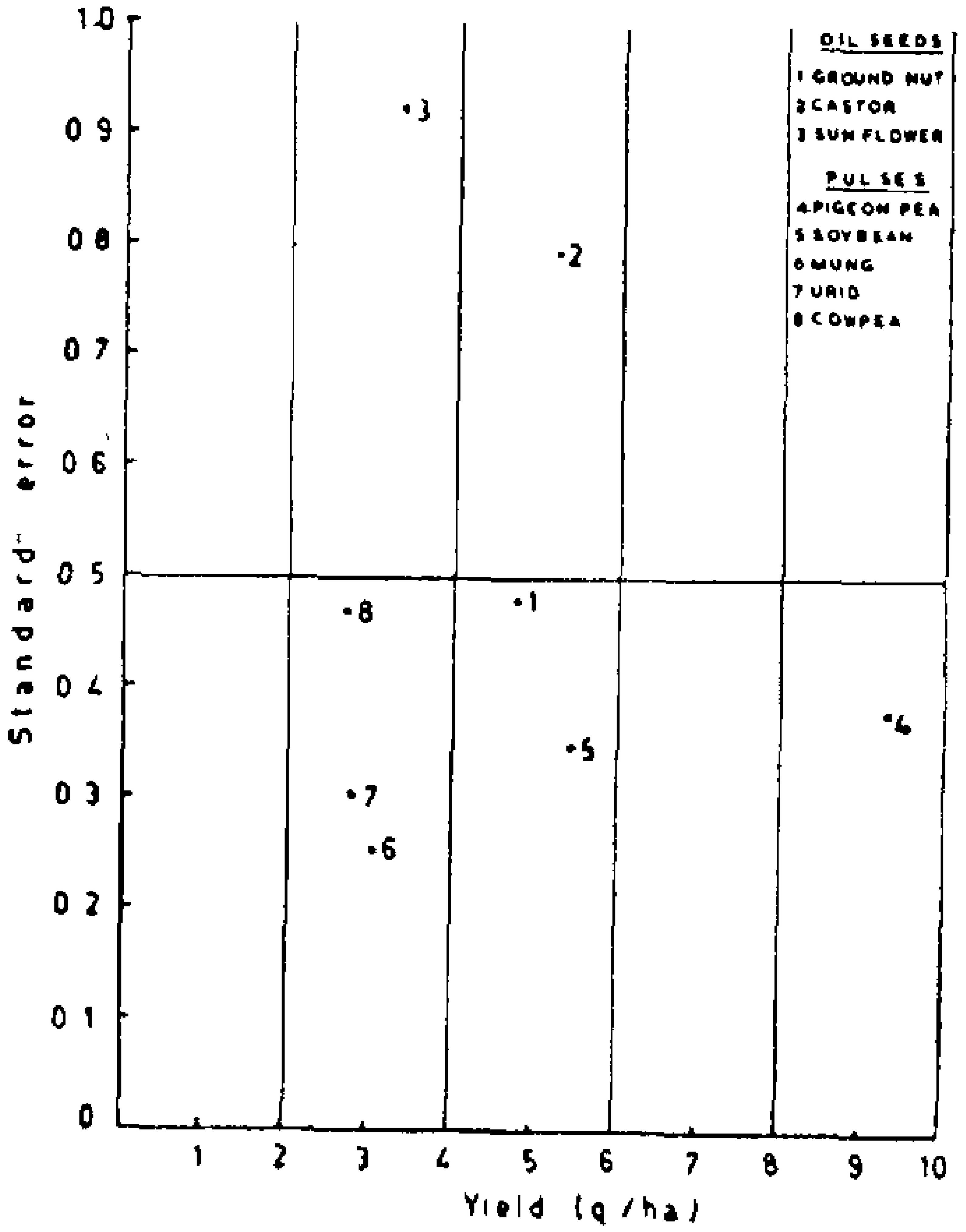

FIG. 4. Average yields of intercrops in relation to the respective standard errors.

TABLE II

Production potential of oilseeds and pulses in sequence cropping in sorghum growing areas

Sequence crop	No. of experiments	Average yield (q/ha)	Projected area (million ha) for 1 million ton production		
			Minimum yield potential	Average yield potential	Maximum yield potential
Safflower (after *kharif* sorghum)	10	9·55±1·62	1·70	1·05	0·76
Chickpea (gram) (after *kharif* sorghum)	5	6·49±1·48	4·20	1·54	0·94
Mung (before *rabi* sorghum)	4	7·05±1·15	2·97	1·42	0·93

could add to pulse production. Short duration sesame could also play an important role as a preceding crop. Based on a two-crop sequence, a million tons of safflower could be produced on an average from 1·05 m. ha, gram from 1·54 m ha, and *mung* from 1·42 m ha. An area of 3 million hectares during *kharif* is an assured single crop area for hybrid sorghums (Fig. 5), particularly hybrids like CSH-5 and CSH-6 which could stand grain deterioration even if late rains are received. The hybrid sorghum could then be followed with a sequence crop of safflower or chickpea.

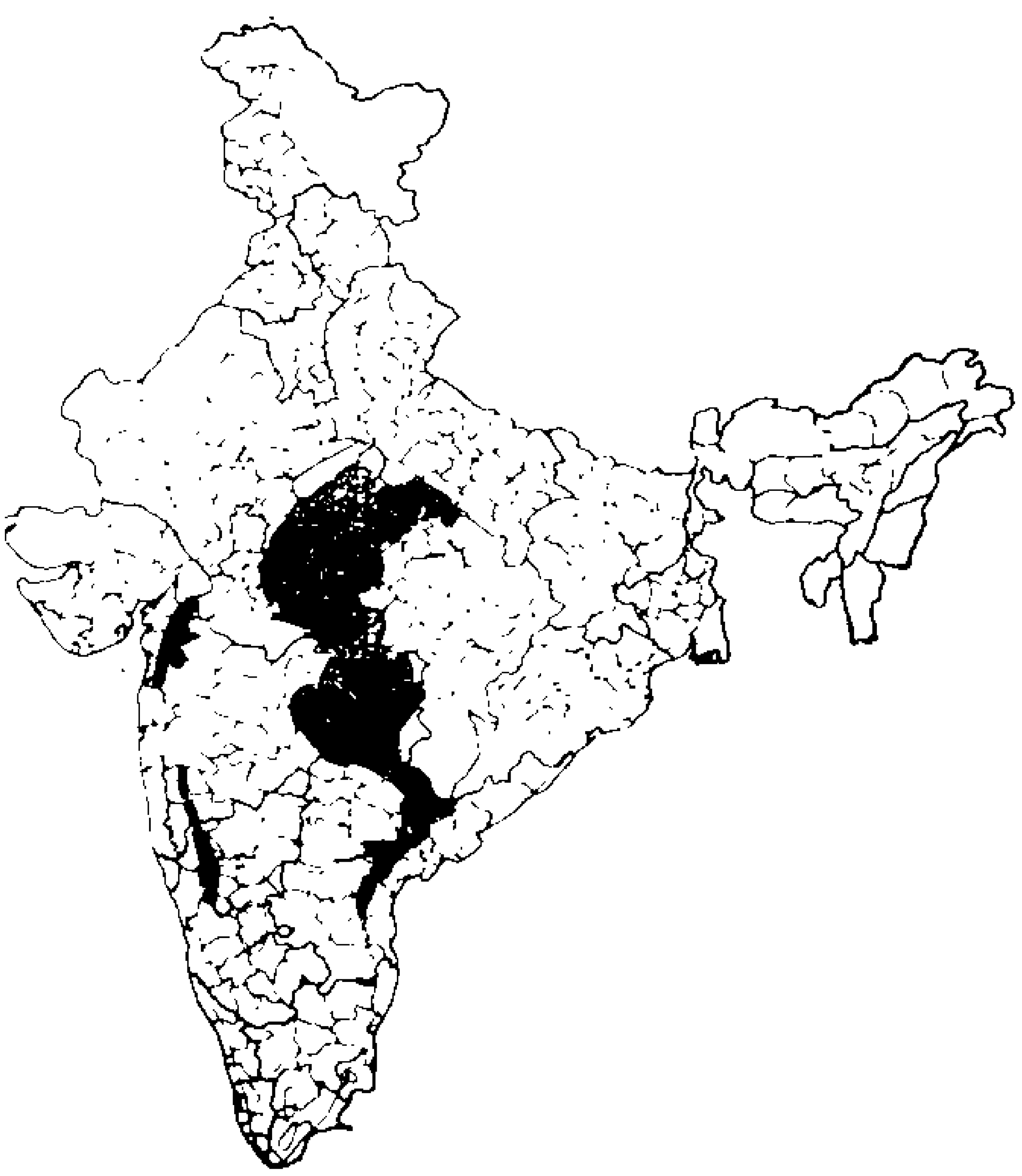

FIG. 5. Sorghum growing districts for potential double cropping under rainfed conditions.

The practice of such sorghum based inter- and sequence cropping systems based on pulse and oil-seed crops enhance the production and productivity of, particularly, small farms. Since pulses and oil-seeds are high value crops, they also compensate for price fluctuations of sorghum and enhance profitability of dryland cropping systems. The introduction of high monetary value crops in cropping systems towards further diversification is now receiving attention.

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