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Computer Programming for Selection of Boom Width and Tank Capacity of Field Sprayers

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Abstract: A computer programme was developed for selection of boom width and tank capacity of field sprayer. The computer model was built up using Visual Basic (ver.6) computer programming language in which input data were inserted directly and output results were obtained easily on the computer screen or as a printout. The model was verified with data collected from some agricultural private companies in Gedarif area, Kenana agricultural implements factory and some data from the literature. The validity of the model was tested, and the results showed close agreement between the field measurements and the computer model predictions. The sensitivity analysis of the model revealed that changes in any of the input parameters used could directly affect the output of the model, such as boom width, tank capacity and work rate. The accuracy of the model was also tested statistically. The model is helpful in proper sprayers management and quick decision-making.

Key words: Computer programming; model; sprayer; boom; tank capacity,

INTRODUCTION

Improvement in agrochemical application technology emphasizes uniform application, precise metering, optimum droplet size and safety towards workers and environment. It is important to apply the required quantity of spray at the right time with complete coverage to the target (Gadalla 1981)

The conventional boom and nozzle spraying system is used as efficient, versatile, effective and safe method of spraying. The chemicals are applied through sprayer nozzles mounted on a boom that receives the chemicals mixture from a sprayer tank. Nozzle flow rate is critical to accurate application of agrochemicals and is dependant on nozzle size, cone angle and pressure (Jain *et al.* 2006).

The sprayer performance is measured by the accuracy of applying chemicals and area covered per unit time; however, both measures are interrelated. Because of the necessity for timeliness when applying chemicals for pest, sprayer boom and tank must be properly selected for spraying the planned area during the scheduled period.

The best way to determine how large a spraying machine needs to be is to determine the necessary capacity to complete the operation within a specified period of time (Bowers 1987).

Tractor-operated sprayers are used for herbicides application in the mechanized rain-fed agriculture in eastern Sudan due to shortage of labour for weeding. The increased adoption rate of this technology among farmers encourages their local manufacturing in Gedarif town, Sudan. Specifications of locally manufactured sprayers are different, especially in boom width and tank capacity. It seems that there is a need for a tool to help farmers in selecting the optimum sprayer specifications. However, a sprayer having a small tank requires frequent refilling, whereas a bigger one is more likely to cause soil compaction and poor traction. Moreover, the use of a wide boom reduces the number of wheeling across the field. A wide boom sprayer can only be used if the land is sufficiently flat (Matthews 1992). Thus, selecting sprayer boom width and tank capacity requires knowledge of area to be sprayed, time available for spraying and the principal components of the sprayer system.

Computer programmes are being used to assist farm manager and scientists in decision making about how to manage their machines or production operations and how to select their machinery requirements (Aderoba 1989; Bol *et al.* 2006; Dahab and Mohamed 2006). The objectives of this study were (i) to develop a computer model for predicting sprayer boom size and tank capacity and (ii) to compare the computer model outputs with actual data from the field to validate the model.

MATERIALS AND METHODS

Model development

The computer programme was developed to predict optimum sprayer boom width (m) and tank capacity (l). The programme was built using Visual Basic (ver. 6) computer Language. The flow-chart of the main programme and the two working procedures are shown in Figs. 1, 2 and 3.

The main features of the programme are the following:

(i) The programme has a capability to enter and edit the input data directly from the screen.

(ii) The programme has no built-in data

(iii) The output can be displayed directly on the computer screen or printed out.

Model description

The computer model is composed of a main programme and two working procedures. The main programme directs the user to input data, select the needed procedure and obtain the final outputs. The user has two options, either to select the procedure for determining boom size or that for specifications of tank.

Procedure one: Determination of sprayer boom width

Practically, not all-available field time in hours (AFT) is used for spraying, thus, time use efficiency (TUE) is computed as follows:

*TUE (%) = Actual spraying time (hr) *100 / AFT per day*……… (1)

*Effective Field Capacity [EFC (fed/hr)] = Area (fed)/(AFT)*TUE*.. (2)

Then, number of nozzles (NN) was calculated as follows:

*NN = (EFC * WAR) / (NFR * cf)* ……………….. (3)

where

WAR = water application rate (L/fed)

NFR = nozzle flow rate (L/min)

Cf = conversion factor (60)

Fed = 0.42 ha

After that, the programme calculates the required boom width (BW) as

$$BW\ (m) = NN * SP \quad \ldots \quad (4)$$

where

SP = spacing between nozzles (m)

The required number of spraying units (NSU) was determined with maximum width available (MABW) as follows:

$$NSU = BW / MABW \quad \ldots \quad (5)$$

Procedure two: Sprayer tank capacity

To determine the tank capacity (TC) of the sprayer in liters, first total water required per day (TWR) in liters was calculated using the following equation:

$$TWR = EFC * WAR * AFT * TUE \quad \ldots \quad (6)$$

Then, the programme calculates the required total tank capacity (TTC) in liters per day using the following equation:

$$TTC = TWR / NLD \quad \ldots \quad (7)$$

where

NLD = number of loads per day (Determined according to distance of water from the spraying area).

The required capacity of the sprayer tank (TC) in liters was determined as follows:

$$TC = TTC / NSU \quad \ldots \quad (8)$$

Model assumptions and limitations

The assumptions and limitations of the model include the following:

(i) The tractive power and the discharge rate of the sprayer pump are not limiting factors.

(ii) All nozzles along the sprayer boom produce the same flow rate.

(iii) No water leakage from the sprayer system and all of the water in the sprayer tank is used for spraying.

Model inputs

The model input parameters are the planned area to be sprayed (fed), available days for spraying operation, available field time per day, time use efficiency, water application rate, nozzle flow rate, spacing between nozzles, maximum available boom width and number of loads/day.

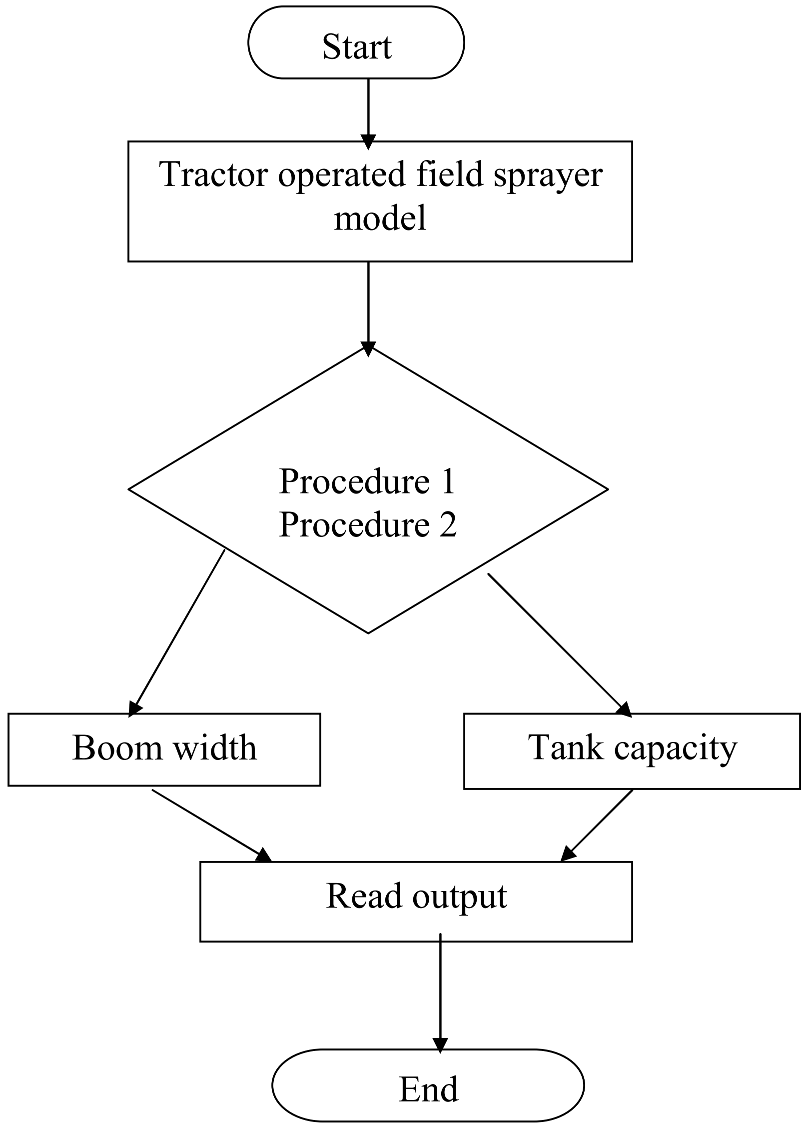

Fig. 1. The main flow chart of the computer model

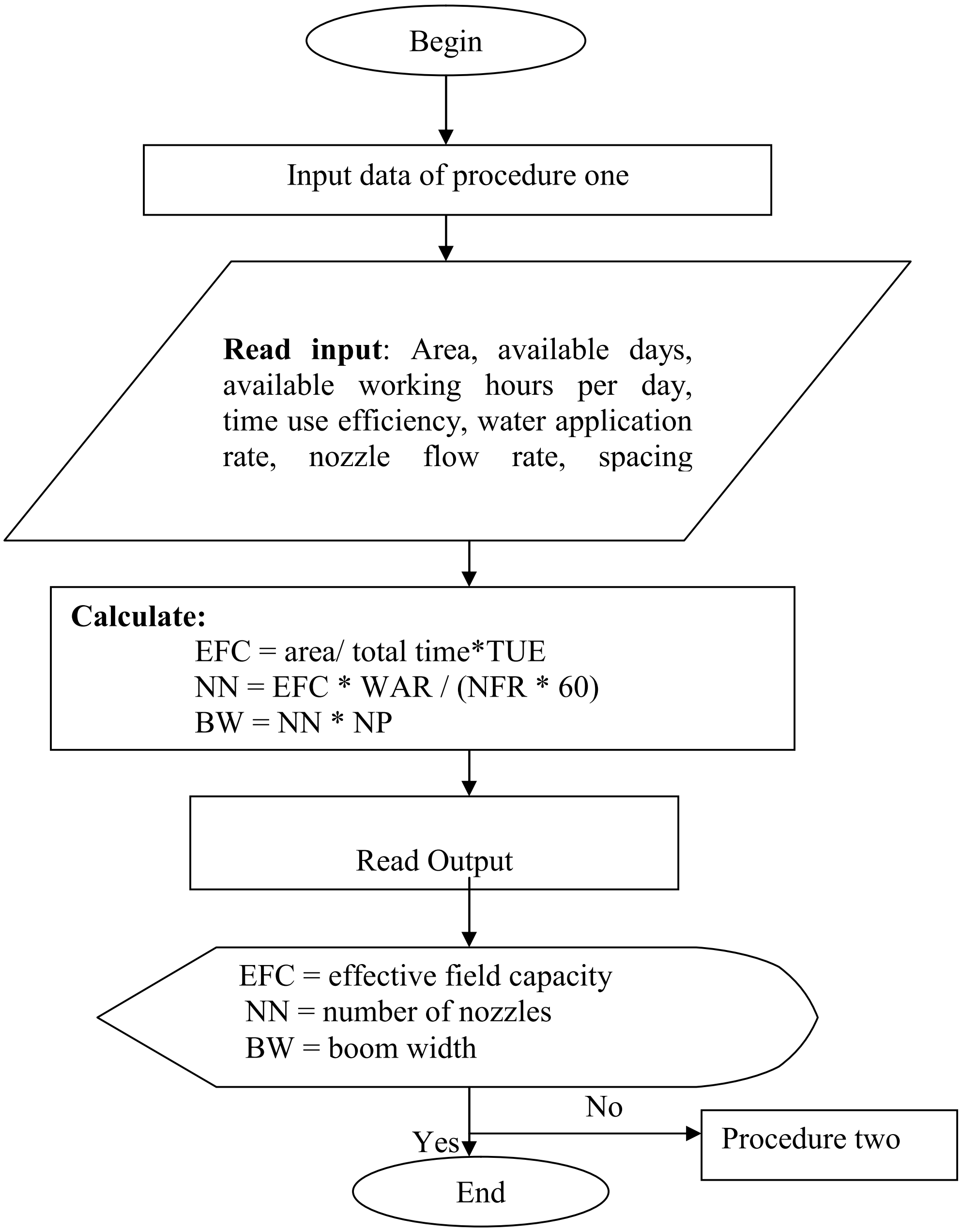

Fig. 2. Flow chart of the model for procedure one

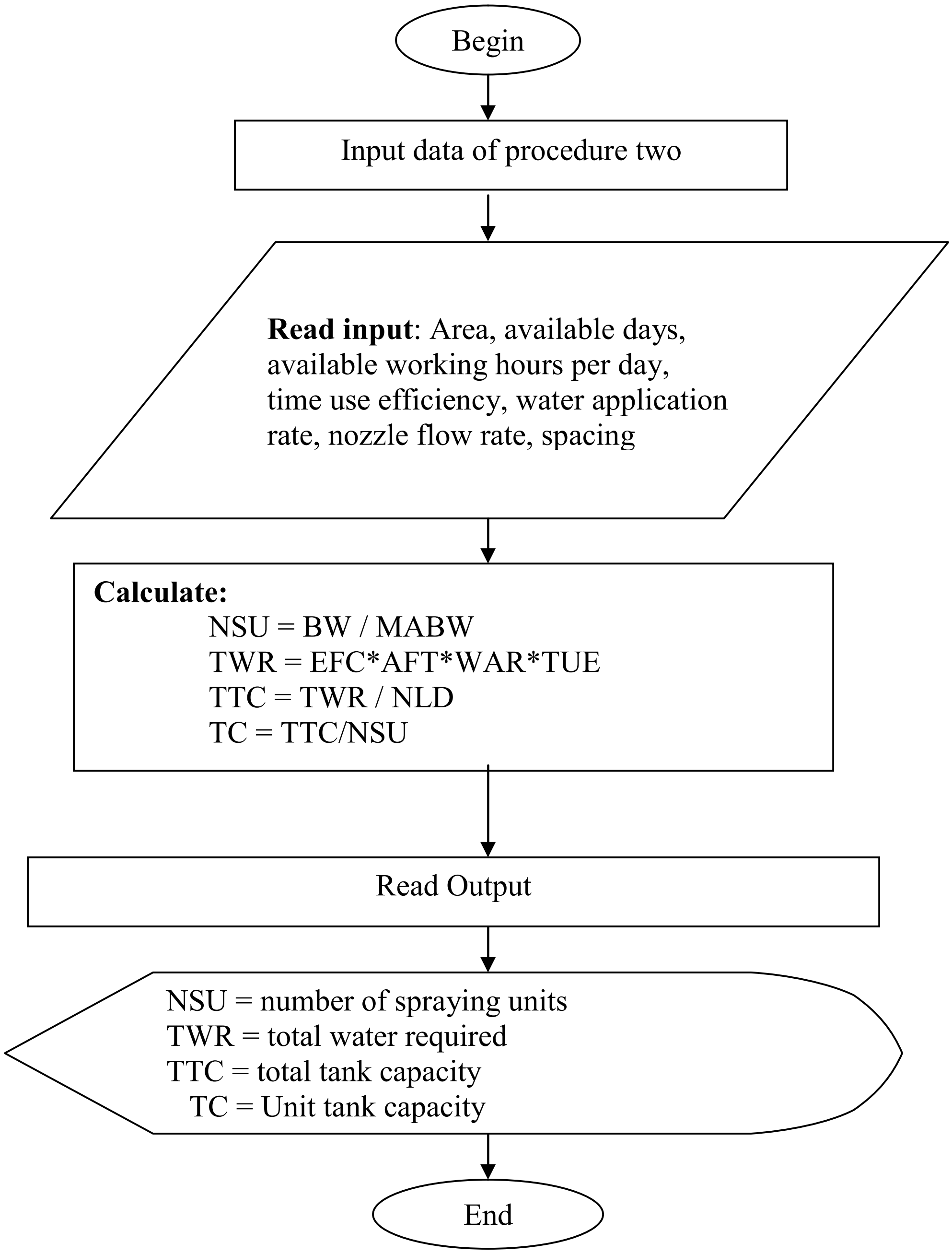

Fig. 3. Flow chart of the model for procedure two

Model outputs

The model outputs are the effective field capacity, number of nozzles, boom width, number of spraying units, total water required per day and tank capacity.

Data for Model verification and validation

To run the programme and to verify the computer model, some data from the literature (Kepner *et al.*1982) and private companies working in chemical spraying in the mechanized rainfed sector of Gedarif area, Sudan, were collected. The data included all of the model input parameters, beside number of nozzles, boom width, tank capacity, effective field capacity and operating speed. Some other data from two agricultural equipment companies in Sudan were used for computer model validation.

RESULTS AND DISCUSSION

Model verification and validation

The computer programme was verified by secondary data from the mechanized rainfed agriculture of eastern Sudan, Gedarif area (Table 1). Other data from Kenana agricultural implements factory and GIAD Company for tractors and agricultural equipments (Sudan) were also used for validating the computer model. The computer model was also validated by comparing the boom width and sprayer tank capacity predicted by the model with actual data obtained from ten tested sprayers (Table 2). There was a close agreement between the predicted and actual data for the boom width (96% - 100%) and for tank capacity (95% - 100%). After validation of the computer model for boom width and tank capacity, the programme was used for prediction of effective field capacity (fed/hr) for the same ten sprayers. The computer predictions were very close to the actual data (Table 3). This confirms the accuracy of the model.

Statistical analysis, using t-test (Snedecor and Cochran 1989), revealed no significant differences ($P > 0.05$) between the actual and predicted parameters (Table 4). This means that the model was well developed and can be useful for estimating and selecting the sprayer boom width and tank capacity

Model application and sensitivity analysis

It was found that changing any of the input parameters can change most of the output parameters in the model. These changes can help in proper sprayer selection and quick decision-making.

The sensitivity analysis showed that decreasing water application rate from 60 to 35 L/fed requires a decrease in boom width and tank capacity of the sprayer by about 42% (Table 5). The results also showed that as time use efficiency decreased from 85% to 55% and other input parameters were kept constant, the effective field capacity and boom width were increased by 54.6% and 50%, respectively. Changes of time use efficiency did not affect tank capacity (Table 6). Model application for the case of Gedarif area indicated that the optimum boom length and tank capacity is 14.3 m and 2000 liters, respectively for standard size of 1000 feddans usually used in the study area, and under conditions specified in Table 5.

CONCLUSIONS

The following conclusions may be drawn from this study:

- The model is capable of estimating the optimum boom width and tank capacity under field working conditions for different types of sprayers.
- The model enables the user to change the input parameters (area, available time, time use efficiency, water application rate and nozzle flow rate) easily and to have new outputs very quickly.
- The model validation revealed that the predictions were in close agreement with the measured data from the field.

Table 1. The used input data to verify the computer model

	Number of sprayers									
	1	2	3	4	5	6	7	8	9	10
Area (fed)	200	180	175	120	240	180	155	120	250	400
Days	1	1	1	1	1	1	1	1	1	1
Hours/day	12	12	12	12	12	10	10	10	10	10
TUE	0.74	0.67	0.65	0.60	0.67	0.66	0.59	0.71	0.74	0.80
WAR (L/fed)	40	40	40	45	50	40	45	50	40	40
NFR (L/ min)	1.5	1.5	1.5	1.5	0.75	1.4	1.5	1.4	1.5	0.7
NS (m)	0.9	0.9	0.9	0.9	0.5	0.9	0.9	0.9	0.9	0.5
MABW	12	12	12	12	12	12	12	12	12	24
NLD	4	4	5	9	6	4	5	10	5	4

TUE= Time use efficiency, WAR= Water application rate, NFR= Nozzle flow rate, SP= Nozzle spacing, MABW = Maximum available boom width (m), NLD = Number of loads per day, fed = 0.42ha

Table 2. Sprayer boom width and tank capacity computer model validation

Boom width (m)			Tank capacity (L)		
Actual	Predicted	Comparative (%)	Actual	Predicted	Comparative (%)
9.0	9.0	100	2000	1990	99
9.0	9.1	99	1800	1811	99
9.0	9.2	98	1400	1388	99
7.2	7.5	96	600	601	100
16.5	16.5	100	2000	2003	100
11.7	11.7	100	1800	1802	100
11.7	11.5	98	1400	1379	98
9.0	8.9	99	600	569	95
13.5	13.5	100	2000	2011	99
24.0	24.2	99	4000	4000	100

Table 3. Computer model application for effective field capacity (EFC) prediction in fed/hr

Sample No.	Actual	Predicted
1	20.0	22.5
2	20.0	22.4
3	20.0	22.4
4	16.7	16.7
5	30.0	29.9
6	27.5	27.3
7	27.0	26.3
8	17.0	16.9
9	34.0	33.8
10	50.0	50.0

Table 4. Paired comparison analysis for the actual and predicted parameters

Parameter	D^{-}	SD^{-}	SD	t Cal.
Boom width (m)	0.00	0.000	0.000	0.00
Tank capacity (l)	0.00	0.615	0.000	1.94
Operating speed (km/hr)	0.07	0.140	0.114	0.45
Effective field capacity (fed/hr)	- 0.60	0.050	1.481	1.28

According to the procedure described by Snedecor and Cochran (1989),
D^{-} = sample mean difference,
SD = standard deviation of the sample difference,
SD^{-} = standard deviation of the sample mean = SD √n
t Cal. = calculated t values = D^{-} / SD^{-}
n= number of the paired samples =10
Degrees (df) of freedom of the paired samples =9
At $t_{0.05}$ and df. = 9, the t value (tabulated) =2.262

Table 5. Effect of changing water application rate on boom width and tank capacity

Water application rate (l/fed)	Boom width (m)	Tank capacity (L)
60	17.1	2401
55	16.2	2201
50	14.4	2001
45	12.6	1801
40	11.7	1601
35	9.9	1401

The used input data to run the model were area = 200 fed, days =1, hours per day =10, time use efficiency = 0.69, effective field capacity = 29 fed/hr, nozzle flow rate = 1.5 L/min, nozzles spacing = 0.9 m, and number of loads per day = 5

Table 6. Effect of changing time use efficiency on effective field capacity, boom width and tank capacity

Time use efficiency (%)	Effective field capacity (fed/hr)	Boom width (m)	Tank capacity (L)
85	19.6	9.0	1799
80	20.8	9.0	1797
75	22.2	9.9	1798
70	23.8	10.8	1799
65	25.6	11.7	1797
60	27.8	12.6	1801
55	30.3	13.5	1800

The used input data to run the model were area = 200 fed, days =1, hours per day =12, water application rate = 45L/fed, nozzle flow rate = 1.5 L/min, nozzles spacing = 0.9 m, and number of loads per day = 5

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برنـامج حاسـوبي لاختيار عـرض الرش وحجـم الخـزان لآلات رش المبيـدات الحقلية

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المستخلص: تم بناء نموذج حاسوبي لاختيار عرض الرش وحجم الخزان لآلـة رش المبيدات. بُني النموذج باستخدام لغة البرمجة الحاسوبية البيسك المرئى (Visual Basic- 6)، حيث ادخلت البيانات مباشرة في البرنامج وتم الحصول على النتائج في الشاشة أو مطبوعة. أختبر النموذج بمعلومات من شركات عاملة في مجال رش المبيدات بمناطق الزراعة المطرية الآلية بالقضارف ومن مصنع كنانة للآلات الزراعية وببعض البيانات المنشورة. أوضحت النتائج توافقا قويا بين القياسات الحقلية وتوقعات النموذج الحاسوبي. كما أوضح تحليل حساسية النموذج أن أي تغيير في البيانات المدخلة يؤثر مباشرة على المعلومات الخارجة مثل عرض خط الرش وحجم خزان المبيد ومعدل الأداء. كما تم أيضا اختبار دقة النموذج إحصائياً. يمكن ان يساعد النموذج في الإدارة السليمة لآلات الرش واتخاذ القرار السريع.