Int.J.Curr.Microbiol.App.Sci (2020) *9*(11): 3120-3128

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 9 Number 11 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.911.376

Correlation Studies and Yield Forecasting Regression Model of *kharif sorghum* [*Sorghum bicolor* (L.)]

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Keywords

Kharif sorghum, Growth stages, Correlation, Regression statistical model

Article Info

Accepted:
22 October 2020
Available Online:
10 November 2020

A B S T R A C T

The field experiment was carried out in *kharif* season 2012-13 for studying relationship between weather parameters and growth of sorghum and to develop the regression model. The sowing date 24thMW showed significantly superior over the rest of treatments with production of highest grain yield (1482.10 kg ha^{-1}) followed by sowing in second sowing date 25thMW (1444.2 kg ha^{-1})and lowest grain yield was observed in fourth sowing date 27th MW (1119.31 kg ha^{-1}). Correlation between weather parameters and growth stages of sorghum with grain yield showed that all the weather parameters mostly positively and highly significant correlation at different growth stages except flag leaf to boot stage. While, it was found highly and negatively significant correlated at all the growth stages expect panicle initiation to flag leaf; boost stage to heading and dough stage with different weather parameters. The multiple regression coefficients (R^2) at each stage showed a high degree of goodness of fit as indicated by as high as 0.74 to 0.88. The regression model for different growth stages was developed and it was found significant. It showed accurate and useful yield prediction because of its error percentage is very less ranging between 0.07 to 4.62 percentages.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is an important food crop in India and it is cultivated in tropical and subtropical climates, especially in the semi-arid tropics. It is the fifth most important cereal crop followed by rice, wheat, maize and barley in the world. In India, sorghum is extensively produced and both hybrid and improved varieties of sorghum are taken on large scale. In Maharashtra state, during *kharif* season jowar is cultivated on 8.82 Mha with production 1.342 Mt and productivity of 1498 kg/hectare. *Rabi* Sorghum plays an important role in dry land economy In Maharashtra. The area under *rabi* sorghum during 2011-12 was 2.38 lakhs hectare with production 1.35 Mt and productivity 567 kg/hectare (Anonymous 2012). Dryland farming is the backbone of Indian agriculture, as large areas of cultivated land are rainfed. The success or failure of dryland rainfed crops depends mostly on the pattern of monsoon rains. The distribution of

rainfall in monsoon decides the yield of rainfed crops. To mitigate these losses of *kharif* sorghum, a field experiment was conducted to find out the suitable sowing date for sustainable yield of rainfed *kharif* sorghum under erratic behavior of monsoon.

Materials and Methods

Field experiment was conducted on yield forecasting regression model of *Sorghum bicolor* (L.) during *kharif* season 2012-13 at Department of Agricultural Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The experiment was conducted in split plot design with three replications and four sowing dates as main treatment *viz*., D_1 (24^{th} MW), D_2 (25^{th} MW), D_3 (26^{th} MW) and D_4 (27^{th} MW) and four different varieties as sub treatment *viz*., V_1 (PSH-71), V_2 (MSH-51), V_3 (BGL-296) and V_4 (PVK-801) were sown with spacing 45x15 cm. The gross plot size was 3.60 x 2.25 $m^2$and net plot size was 2.25x 1.8 m^2. The sowing of seed was done by dibbling method on respective date of sowing. Recommended packages of practices like thinning, weeding, application of recommended dose of fertilizer i.e. NPK (80:40:40 $kgha^{-1}$ respectively) and pesticide were uniformly applied to each treatment.

Observations on plant were recorded on five plants randomly selected in each replication of all treatments. The data recorded were statistically analyzed by using computerized programme based on technique of analysis of variance and significance for every phenophase of sorghum crop. Regression equation was developed on the basis of crop data (phonological stage wise data) and weather data. The multiple regression was worked out at different growth stages of sorghum i.e. emergence to panicle initiation (P_2), flag leaf to boot stage (P_4), heading to 50 % flowering (P_6), flowering to milk stage (P_7), dough stage (P_8) and physiological maturity (P_9) stage. While, for forecasting the yield, most commonly used model are based on following type i.e. multiple regression model and it is given as below.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots. \beta_i X_i$$

Where,

Y is yield (Dependent parameter) , Xi is weather parameters (independent parameters) and β_0 and β_i, are constants**.**

Results and Discussion

Weather condition during crop growth period

Total rainfall during crop growth period (24^{th} MW to 45^{th} MW) received was 673.9 mm in 41 rainy days. The maximum and minimum temperature during crop growing period was ranged in between 30.0 to 38.4 ^{0}C and 15.6 to 26.3 ^{0}C respectively. The morning relative humidity (RH-I) ranged in between from 61 to 95 percent and afternoon relative humidity (RH-II) 26 to 72 percent during crop growing season.

It is observed that average evaporation 5.24 mm day^{-1} during the crop grooving period; lowest and highest evaporation was recorded 2.8 mm (36^{th} MW) and 11.2 mm in (24^{th} MW), respectively. The mean BSS during crop growing period (from 24^{th} to 45^{th} MW) was recorded 6.39 hrs day^{-1}. The highest value of bright sunshine hours was recorded in 42 MW (10.1 hrs day^{-1}) and lowest BSS in 25 MW (2.7 hrs day^{-1}). Highest wind velocity (7.9 km hr^{-1}) was recorded in 24^{th} MW and lowest wind velocity (2.0 km hr^{-1}) was recorded in 41 MW. While, it was recorded average 4.95 km hr^{-1} during the whole crop growing period.

Yield attributes

Test weight (gm)

The data given in table 1 for test weight (gm per 1000 seeds) is revealed that the mean test weight of *kharif* sorghum varieties was recorded 30.43 gm and the second sowing (i.e. 25 MW sowing) showed significantly highest mean thousand seed weight (31.66 gm) over the other of sowing dates and it was at par with sowing in 24 MW (30.60 gm) and 27 MW (31.28 gm) sowing date. The similar results were reported by Sonwar *et al.,* (2008) and he stated that the early sowing of kharif sweet sorghum gives highest test weight. It may be due to obtaining most congenial weather condition at each phenophase.

The effect amongst four varieties in thousand seed weight was found significant and the PSH-71 variety observed significantly superior over all the varieties (31.83 gm) in mean thousand seed weight. While, it was at par with variety BGL-296 (31.08 gm). It may be due to varietal characters i.e. yield response to weather parameters. The interaction effect between date of sowing and different cultivars was found to be non-significant.

Grain yield (kg ha^{-1})

The mean grain yield per hectare of *kharif* sorghum (Table 1) was recorded 1335.9 kg ha^{-1} and significantly highest grain yield (1482.10 kg ha^{-1}) was recorded in 24th MW sowing and it was at par with 25th MW sowing (1442.2 kg ha^{-1}). While, lowest grain yield (1119.31 kg ha^{-1}) was recorded in 27th MW. Similar results were reported by Umrani *et al.,* (1988), Baig and Shankiti (1994), Bhoite and Nimbalkar (1997), Sunil Kausik *et al.,* (2007), Jadhav *et al.,* (2010).

Amongst the four varieties highest grain yield per ha^{-1} was observed in variety PSG-71 (1451.31 kg ha^{-1}) and lowest in PVK-801 (Parbhani sweta) (1230.2 kg ha^{-1}). The variety PSH-71 was recorded significantly superior yield over all the remaining varieties. The interaction effect between date of sowing and different varieties was found to be non-significant for grain yield.

Fodder yield

It is understood from the table 1, that the mean fodder yield was recorded 6908.9 kg ha^{-1}. Second sowing date 25th MW recorded significantly highest fodder yield (7310.5 kg ha^{-1}) and lowest in 27th MW (6541.1 kg ha^{-1}). Similar results were reported by Alma *et al.,* (1995).

The significant differences in fodder yield amongst the varieties was observed and highest and lowest fodder yield was recorded in variety PSH-71 (7228.2 kg ha^{-1}) and variety MSH-51 (6484.7 kg ha^{-1}), respectively. The significantly highest fodder yield was recorded in PSH-71 (7288.2 kg ha^{-1}) over all the rest treatments and it was at par with MSH-51 (7069.9 kg ha^{-1}).

Biological yield

The data given in table 1 interprets that the sowing in 24th MW significantly highest biological yield was recorded in 24th MW (8743.4 kg ha^{-1}); While, it was at par with sowing in 25th MW(8741.8 kg ha^{-1}) while, it was observed lowest (7660.41 kg ha^{-1}) in 27 MW with mean biological yield (8244.21 kg ha^{-1}). Similar results were reported by Suchit K. Rai *et al.,* (2006).

Amongst the four varieties highest biological yield was observed in variety PSH-71 (8679.51 kg ha^{-1}) and lowest biological yield was recorded in MSH-51 (7794.2 kg ha^{-1}). While, it was at par with variety Bhagyalaxi-296 (8422.6 kg ha^{-1}).

Correlation between weather parameters and different growth stages with grain yield

The data of weather parameters for correlation was taken (*viz*., rainfall, rainy day, temperature, relative humidity, bright sunshine hours, wind speed and evaporation etc.) commutatively and averagely during sorghum crop growing season for all sowing dates and at each phenophase and correlated with yield (Table 2). Weather parameters found significantly correlated with sorghum grain yield at different growth stages. However, highly and positively significant correlation was found at sowing to emergence with wind velocity (r =0.732**); at emergence to panicle initiation with evaporation (r =0.640**) and bright sunshine hours (r = 0.714**); at panicle initiation to flag leaf stage with wind velocity (r = 0.664**); boot stage to heading with maximum temperature (r =0.629**); at heading to 50% flowering with minimum temperature (r =0.633**); at flowering to milk stage with rain fall (r = 0.850**), rainy days (r =0.751**) and relative humidity-I (r = 0.721**); at dough stage with wind velocity (r = 0.726**) and at Physiological maturity with rainfall (r= 0.831**), rainy days (r= 0.823**), maximum temperature (r=0.801**) and minimum temperature (r= 0.830**). However, it was found negatively and highly significant relation at sowing to emergence with of RH-I (r= -0.747**) and RH-II (r= -0.715**);at emergence to panicle initiation with rainy days (r= -0.656**); with BSS (r= -0.688**, r= -0.713**,-0.802**) at Flag leaf to Boot stage, Heading to 50% flowering and Flowering to milk stage, respectively and with maximum temperature (r= -0.722**), Evaporation (r= -0.668**) and BSS (r= -0.749) at Physiological maturity.

As per discussed above, highly and positively or negatively influencing weather parameters on crop growth, development and yield of sorghum was observed (Table-2). However, some weather parameters at different growth stages showed positive as well as negative significant effect on growth and yield of sorghum.

It is clearly understood from the table -2 that during initial crop growth stages (sowing to heading) less significant weather parameters was observed minimum temperature and later growth stages (heading to dough stages) afternoon relative humidity and evaporation.

It means that more or less impact of all weather parameters observed directly on yield of sorghum crop with maximum impact of rainfall, rainy days, maximum temperature and bright sunshine hours (BSS).

Correlation between weather parameters and different growth stages with fodder yield

The data of weather parameters for correlation was taken (*viz*., rainfall, rainy day, temperature, relative humidity, bright sunshine hours, wind speed and evaporation etc.) commutatively and averagely during sorghum crop growing season for all sowing dates and at each phenophase and correlated with fodder yield (Table 3). Weather parameters found significantly correlated with sorghum fodder yield at different growth stages. However, highly and positively significant correlation was found at sowing to emergence with evaporation (0.705**); at emergence to panicle initiation positively significant correlation with evaporation (r =0.555*) and bright sunshine hours (r = 0.652**); at panicle initiation to flag leaf stage positively significant correlation with rainfall and rainy days (r = 0.711**) wind velocity (r = 0.689**); at flag leaf to boot stage positively significant correlation with afternoon relative humidity (r =0.715**); at

boot stage to heading with wind speed (r =0.713**); at Heading to 50% flowering stage positively significant correlation with minimum temperature (r=0.705**) maximum temperature (r = 0.548*); flowering to milk stage with rain fall (r = 0.682**), rainy days (r =0.696**) and relative humidity-I (r = 0.641**) relative humidity-II (r = 0.686**); at dough stage positively significant correlation with minimum temperature (r=0.624**) and with wind velocity (r = 0682**) and at Physiological maturity with rainy days (r = 0.578*), minimum temperature (r = 0.518*), relative humidity-I (r = 0.507*) and relative humidity-II (r = 0.520**);

However, it was found negatively and highly significant relation at sowing to emergence with of RH-I (r = -0.589*); at emergence to panicle initiation with rainy days (r = -0.656**); with rainfall (r = -0.642**, r = -0.660**,) Rainy days (r = -0.654**), r = -0.627**) R.H. - I (r = -0.692**, r= -0.649**) at Flag leaf to Boot stage, at Boot stage to heading respectively. And also Tmax (r=-0.688**) R.H.-II (r= -0.681**);at Heading to 50% flowering minimum temperature (r= -0.705**) and BSS (r= -0.693**); at Flowering to milk stage maximum temperature (r = -0.642**)evaporation (r= --0.658**) and BSS(r= -0.703**) ; at Dough stage maximum temperature (r = -0.714**)

Table.1 Mean test weight (gm 1000 grain^{-1}), grain yield (kg ha^{-1}), fodder yield (kg ha^{-1}) and biological yield (kg ha^{-1})

Treatments	Test weight (gm)	Grain yield (kg ha^{-1})	Fodder yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Date of Sowing				
24 MW	30.60	1482.10	7261.3	8743.4
25 MW	31.66	1431.30	7310.5	8741.8
26 MW	31.28	1311.00	6522.6	7833.6
27 MW	28.19	1119.31	6541.1	7660.41
SE ±	0.76	26.62	174.46	178.62
CD at 5 %	2.24	77.59	508.46	520.56
Varieties				
PSH-71	31.83	1451.31	7228.2	8679.51
MSH-51	29.25	1309.50	6484.7	7794.2
BGL-296	31.08	1352.7	7069.9	8422.6
PVK-801	29.58	1230.2	6847.7	8077.9
SE ±	0.50	23.23	179.77	183.96
CD at 5 %	1.47	67.71	523.92	536.13
D x V Interaction				
SE ±	1.01	46.47	359.54	367.91
CD at 5 %	NS	NS	NS	NS
G.M	30.43	1335.9	6908.9	8244.21

Table.2 Correlations between weather parameter and different growth stages of sorghum with grain yield

Weather parameters	Phenophase stages in Sorghum								
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Rainfall (mm)	0.113	-0.456	0.531*	0.507*	0.105	-0.603*	0.850**	0.484*	0.831**
Rainy days	-0.247	-0.656**	0.562*	-0.528*	0.540*	-0.385	0.751**	0.512*	0.823**
Tmax (°C)	0.543*	0.581*	0.107	0.035	0.629**	0.335	-0.539*	-0.372	-0.772**
Tmin (°C)	0.322	0.005	0.592*	-0.286	-0.532*	0.633**	0.234	0.615*	0.801**
RH - I (%)	-0.747**	-0.603*	0.657**	-0.590*	-0.595*	-0.152	0.598*	0.591*	0.830**
RH - II (%)	-0.715**	-0.524*	0.205	0.539*	0.194	-0.222	0.721**	0.440	0.617*
Evp (mm)	0.743**	0.640**	0.476*	-0.610*	-0.275	0.040	-0.462	-0.211	-0.668**
B.S.S (hrs)	0.236	0.714**	-0.601*	-0.688**	0.288	-0.713**	-0.802**	-0.469	-0.749**
W.V (Kmhr $^{-1}$)	0.732**	-0.621*	0.664**	0.517*	0.131	-0.329	0.590*	0.726**	0.400

(* Significant at 0.05%, ** Significant at 0.01%)

P_1- Sowing to emergence **P_2** - Emergence to panicle initiation (PI) **P_3** – PI to flag leaf stage
P_4- Flag leaf to boot stage **P_5**- Boot stage to heading **P_6** –Heading to 50% flowering
P_7- Flowering to milk stage **P_8**- Dough stage **P_9**- Physiological maturity

Table.3 Correlations between weather parameter and different growth stages of sorghum with fodder yield

Weather parameters	Phenophase stages in Sorghum								
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Rainfall (mm)	0.036	-0.289	0.711**	-0.642**	-0.660**	-0.391	0.682**	0.336	0.481
Rainy days	-0.238	-0.462	0.711**	-0.654**	-0.627**	-0.404	0.696**	0.333	0.578*
Tmax (°C)	0.588*	0.427	0.040	-0.055	-0.688**	0.548*	-0.642**	-0.714**	-0.532*
Tmin (°C)	0.668**	-0.169	0.3970	-0.663**	-0.460	0.705**	0.486	0.624**	0.518*
RH - I (%)	-0.589*	-0.520*	0.203	-0.692**	-0.649**	-0.521*	0.641**	0.197	0.507*
RH - II (%)	-0.405	-0.494	0.219	0.715**	-0.681**	-0.567*	0.686**	0.273	0.520*
Evp (mm)	0.705**	0.555*	0.301	-0.623**	0.712**	0.436	-0.658**	-0.506*	-0.344
B.S.S (hrs)	0.223	0.652**	-0.412	-0.547*	-0.620*	-0.693**	-0.703**	-0.609*	-0.395
W.V (Kmhr $^{-1}$)	0.600*	-0.284	0.689**	0.511*	0.713**	-0.418	0.088	0.682**	0.589*

(* Significant at 0.05%, ** Significant at 0.01%)

P_1- Sowing to emergence **P_2** - Emergence to panicle initiation (PI) **P_3** – PI to flag leaf stage
P_4- Flag leaf to boot stage **P_5**- Boot stage to heading **P_6** –Heading to 50% flowering
P_7- Flowering to milk stage **P_8**- Dough stage **P_9**- Physiological maturity

Table.4 Predicted and observed grain yield (kg ha^{-1}) of sorghum by multiple regression at various phenophases stages

Phenophase	Predicted Yield (kg ha^{-1}) (P)	Observed Yield (kg ha^{-1}) (O)	Difference (kg) (P-O)	Error (%)
P_2	1334.90	1335.85	-0.95	0.07
P_4	1319.68	1335.85	-16.17	1.21
P_6	1328.79	1335.85	-7.06	0.52
P_7	1325.05	1335.85	-10.76	0.80
P_8	1396.80	1335.85	60.95	4.62
P_9	1363.11	1335.85	27.26	2.04

P_2 - Emergence to panicle initiation **P_4**- Flag leaf to boot stage
P_6 –Heading to 50 % flowering **P_7**- Flowering to milk stage
P_8- Dough stage **P_9**- Physiological maturity

Table.5 The multiple regression equation fitted with weather parameter at different growth stages

Sr. No.	Phenophase stages in Sorghum	Multiple regression equation	R^2
1	Emergence to panicle initiation	$Y = -29380.5 - 10.93 X_1 + 212.34 X_2 + 251.9643 X_3 + 309.34 X_4 + 81.15 X_5 - 8.99 X_6 + 2964.00 X_7 - -640.95 X_8 - 1053.08 X_9$	0.88
2	Flag leaf to boot stage	$Y = -33190.0 + 359.92 X_1 - 5560.80 X_2 - 505.49 X_3 + 32.90 X_4 + 333.05 X_5 + 256.66 X_6 + 3241.52 X_7 - -1469.99 X_8 + 137.25 X_9$	0.86
3	Heading to 50 % flowering	$Y = -11245.2 - 5.527 X_1 + 239.13 X_2 + 123.40 X_3 + 95.72 X_4 + 75.30 X_5 - 12.36 X_6 - 705.02 X_7 - 216.72 X_8 + 1104.24 X_9$	0.79
4	Flowering to milk stage	$Y = -7924.50 - 10.37 X_1 - 156.37 X_2 + 55.11 X_3 + 32.24 X_4 + 61.27 X_5 - 6.44 X_6 + 189.02 X_7 + 153.51 X_8 - 46.58 X_9$	0. 79
5	Dough stage	$Y = -4503.24 - 36.83 X_1 + 949.45 X_2 + -25.19 X_3 - 297.97 X_4 + 89.07 X_5 + 132.05 X_6 + 1544.69 X_7 - 1264.23 X_8 - 447.09 X_9$	0.74
6	**P_9**- Physiological maturity	$Y = 4280.19 + 7.59 X_1 + 18.23 X_2 - 119.45 X_3 - 125.19 X_4 + 25.87 X_5 + 10.51 X_6 + 56.29 X_7 + 113.66 X_8 - 263.93 X_9$	0.80

Where, X_1= Rainfall,X_2 = rainy day, X_3 = Tmax,X_4 =Tmin, X_5 = RH-I, X_6 = RH-II,
X_7 =EVP, X_8 =BSS,X_9 =Wind velocity
R^2 = multiple regression coefficient

Statistical model for yield forecasting

The multiple regression between weather parameter and grain yield at different critical growth stages of sorghum worked out and multiple regression equation was derived at different growth stages of sorghum *viz.*, emergence to panicle initiation (PI), flag leaf to boot stage, heading to 50 % flowering, flowering to milk stage, dough stage and physiological maturity, respectively. The multiple regression equation fitted with weather parameter at different growth stages in order to forecast the sorghum grain yield (Table 5). These above multiple regression equations are resembled with

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots. \beta_i X_i$

Where, Y is yield (Dependent parameter) and X_i are weather parameters (independent parameters) respectively, β_0 and β_i are constants**.**

The multiple regression coefficients (R^2) at each stage showed a high degree of goodness of fit as indicated by as high as 0.79 to 0.88. The multiple regression models were found significant and similar results are given by Rana *et al.,* (1998).

The regression model developed for different growth stages showed accurate and useful prediction because of its error percentage is very less and it is ranged in between 0.07 to 4.62 percentages.

Data given in Table 4 is indicated that error percentage in between predicted grain yield at different growth stages and actual recorded grain yield (i.e. observed yield) compared. The observed yield was compared with estimated yield; developed by multiple regression model and percentage error in estimated yield is also calculated (Table-4) at different growth stages *viz.*, at emergence to panicle initiation (-0.07 %), flag leaf to boot stage(-1.21 %), heading to 50% flowering (-0.52 %) and at flowering to milk stage (-0.80 %) stage. While, it was observed over estimated at dough stage (4.62 %) and at physiological maturity (2.09 %). It means that the regression model developed for different growth stages of sorghum showed accurate and useful yield prediction with low percentage error.

However, validation of this regression model is required for practical utilization to give yield prediction at different growth stages of *Kharif* sorghum before harvesting one month to two and half month.

Conclusion of the study is as follows:

On the basis of observed, tabulated and analyzed data (i.e. biometric and yield contributing character, it is recommended that sowing may be done in 24 MW (11 to 17 June) for grain yield, followed by sowing in 25th MW (18 to 24 June) for highest grain and fodder yield and variety PSH-71 optimum for sowing in *Kharif* season at Parbhani location in Marathwada region.

The multiple regression model at flag leaf to boot stage and physiological maturity stage is $Y = -33190.0 + 359.92\ X_1 - 5560.80\ X_2 - 505.49\ X_3 + 32.90\ X_4 + 333.05\ X_5 + 256.66\ X_6 + 3241.52\ X_7 - -1469.99\ X_8 + 137.25\ X_9$ and $Y = 4280.19 + 7.59\ X_1 + 18.23\ X_2 - 119.45\ X_3 - 125.19\ X_4 + 25.87\ X_5 + 10.51\ X_6 + 56.29\ X_7 + 113.66\ X_8 - 263.93\ X_9$ is significant and it may be used to yield forecast of *Kharif* sorghum in advance two to two and half months and 15 days before harvesting at Parbhani location.

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How to cite this article:

Burade, D. D., M. B. Jadhav and Nirwal, A. D. 2020. Correlation Studies and Yield Forecasting Regression Model of *kharif sorghum* [*Sorghum bicolor* (L.)]. *Int.J.Curr.Microbiol.App.Sci.* 9(11): 3120-3128. doi: https://doi.org/10.20546/ijcmas.2020.911.376