

**DIALLEL ANALYSIS OF SWEET POTATO [*IPOMOEA BATATUS* (L.) LAM]
GENOTYPES FOR COMBINED BETA CAROTENE AND DRY MATTER CONTENT
IN SOUTHERN GUINEA SAVANNA, NIGERIA.**

Abstract

Roots of orange fleshed sweet potato varieties currently available in Nigeria contain high quantities of β -carotene or pro-vitamin A but have high moisture content. These varieties have been found to be a cheap and crucially important remedy for vitamin A deficiency. The cream or white fleshed varieties on the other hand, have a sweet taste with high dry matter content, giving a dry texture, a quality trait preferred in Nigeria. Development of sweet potato genotypes that can combine these two important quality traits is the objective of this breeding work.

A diallel experiment using six parental sweet potato genotypes crossed in all possible combinations were carried out and thirty progenies were evaluated for beta carotene (β -carotene) and dry matter content in Landmark University, Omu Aran, Kwara State, Nigeria. The 30 F_1 progenies along with their parental lines were planted in the same field trial. The trial was laid out in 6 x 6 triple lattice in two replications. Highly significant ($P \leq 0.01$) differences were observed among the genotypes for the traits. The average β -carotene content among the progenies was 2.86 (mg/100g.f.w) while the dry matter content had a mean value of 31.89%. The cross progenies 199024.2 x Excel had the highest beta carotene (14.37mg/100g.f.w) content with highest dry matter content (40.10%) and are therefore recommended for further evaluation.

Key words: Diallel analysis; dry matter; Southern Guinea Savanna; sweet potato; Vitamin A, β -carotene.

27 INTRODUCTION

28 Sweet potato [*Ipomoea batatas* (L.) Lam] is the seventh most important crop in the world
29 with an estimated 124 million metric tons produced annually. In the tropics, sweetpotato ranks
30 fifth in terms of caloric contribution after rice, wheat, maize, and cassava [1,2]. In many
31 developing countries, sweetpotato is a staple because they are easy to propagate and maintain,
32 and yield well under a variety of adverse conditions, including drought. The potential of this crop
33 as a food, and carbohydrate source is widely recognized [3].

34 Sweet potato is one of the most under exploited of the developing world's major crops
35 [4] as evidenced by its breeding initiatives that are at relatively early stages compared to other
36 crops. The need to identify local germplasm with desirable traits has long been recognised by
37 breeders [4]. It has been long known that many sweetpotato traits are mainly quantitatively
38 inherited [5]. To meet the quality needs there is a need to take into account the farmer and
39 consumer preferences when developing and selecting sweetpotato varieties and in most cases this
40 can be addressed through participatory variety selection. Fortunately, the attributes considered
41 most important by farmers and consumers were already identified and ranked by [4]. Given the
42 enormous genetic diversity of sweet potato in Uganda [6], the possibility for sweetpotato
43 improvement to accommodate specific uses is expected to be rapid [4]. There is wide genetic
44 variability for vitamin A occurring naturally in sweetpotato. This means conventional breeding
45 techniques can be employed to combine β -carotene and dry matter into sweetpotato varieties.

46 Diallel mating designs have been widely used in genetic research to investigate the
47 inheritance of important traits in a set of genotypes [7, 8]. Diallel mating designs were devised,
48 specifically to investigate the combining ability of the parental lines for the purpose of

49 identification of superior parents for use in hybrid development programmes. A diallel cross is a
50 set of p^2 possible single crosses and selfs between p homozygous [9,10,11,12] or heterozygous
51 [13] parents; it provides a powerful method for investigating the relative genetic properties of
52 these parents. It is possible to partition treatment variation into components due to general
53 combining ability (GCA) and specific combining ability (SCA) [14, 7, 16, 17]. General
54 combining ability (GCA) is the average performance of a genotype in hybrid combination while
55 Specific combining ability (SCA) are those cases in which certain combinations perform
56 relatively better or worse than expected on the average [18]. The estimates of the relative
57 magnitude of the variances of GCA and SCA indicate the type of gene action determining the
58 traits. Variance due to GCA indicates the predominance of additive gene action while that of
59 SCA indicates the predominance of non-additive gene action arising largely from dominance and
60 epistatic deviations [19]. The present research examined the quantitative inheritance of important
61 traits in sweet potato by means of a diallel analysis with a view to estimating the GCA and SCA
62 components of genetic variance, and to determine the associated type of gene action controlling
63 β -carotene content and root dry mass.

64

65 **2. Materials and Methods**

66 2.1. Description of the Study Area

67 A field experiment was conducted on six sweet potatoes genotypes (three orange flesh
68 and three white flesh) at the Teaching and Research Farm of Landmark University, Omu Aran,
69 Nigeria. The experimental site is located at the Southern Guinea Savanna agro-ecological zone of
70 Nigeria with distinct wet and dry seasons. The land had been used continuously for the
71 cultivation of arable crops like maize, melon, cowpea and vegetables for more than three years.
72 Soil samples were collected from the trial site before cropping and were analyzed in the
73 laboratory for physical and chemical properties (Table 2). The soil texture was loamy sand.

74

75 2.2. Treatments and Experimental Design

76 The parents materials used for the experiment were obtained from the germplasm
77 collection centre of the Department of Agronomy, University of Ibadan which was originally
78 from the listed sources in Table 1. The parents were selected on the basis of being cross-
79 compatible. Hand crosses were carried out in a 6 x 6 full diallel, excluding selfs from 2010 to
80 2011 at the Teaching and Research Farm of Landmark University, Omu Aran, Nigeria. Fruits
81 were harvested between 30-50 days after pollination in the early morning to prevent scattering.
82 The fruits were further air dried, shelled, put in a labeled envelope and kept in desiccators. The
83 harvested seeds were soaked in water over night and planted into polythene bags filled with
84 loamy soil. Once the plants were about 30cm tall, they were transplanted to well-prepared ridges
85 for further growth and development. Twenty cuttings of 25cm length of the sweet potato vines
86 from F₁ progeny were made to represent each cross. The selected 30 F₁ progeny along with their
87 parental lines were planted in the same field trial. The trial was laid out in 6 x 6 triple lattice in
88 two replications. The plot size used was 3m x 1m in two rows. Each plot comprised the 20
89 cuttings from each progeny of a cross. Each vine was inserted at a slant, with two-third buried
90 below the soil surface. Weeding was done 4, 6 and 8 weeks after planting, using small hoes. No
91 herbicides or fertilizers were applied. Appropriate agronomic practices were followed to raise a
92 good crop.

93 2.3. Data Collection

94 All data were recorded on individual plant basis and then averaged across the 20 progeny
95 of each F₁ cross. The quantitative traits were evaluated as follows: β - carotene content expressed
96 as mg 100 g⁻¹ and dry matter content (g) expressed as a percentage of root fresh mass (g).

97

98

100 2.4 Statistical analysis of triple lattice

101 Data collected on the two traits were subjected to diallel analysis using Griffing (1956)
102 Method II (parents and crosses together), Mixed I (fixed effects). Both general and specific
103 combining abilities were computed using [20] for the parent and crosses.

104 Diallel analysis

105 To test the null hypothesis of no genotypic differences among parents and crosses, one
106 way analysis of variance was performed. Treatment sum of squares were partitioned into three
107 components, parents (P), crosses (C), and parent vs. crosses (P. vs. C.). General Combining
108 Ability and Specific Combining Ability variance components of the cross mean square were
109 computed according to Griffing's (1956) fixed-effects model I. Reciprocals were defined as
110 being below the diagonal. Adopting [14] notation the following genetic statistical model for an
111 analysis within one environment.

112 3. Results

113 3.1 Analysis of variance for β -carotene and dry matter content

114 β -carotene content and dry matter content means squares were both significant ($p < 0.01$) among
115 the parents and their 30F1 families, this shows that there are genetic variation among the parents
116 and their crosses as shown in table 4. Crosses out-performing their parents can be attributed to
117 transgressive segregation which is desirable for improving β -carotene content and dry matter
118 content. The results of average performances of some of the crosses presented in table 5 shows
119 that the performances of crosses are significantly higher than the two parents for the traits. Cross
120 1 x 3 had the highest values in term of β -carotene and dry matter content with means of 14.37 mg
121 100 g^{-1} and 40.10% respectively followed by 1 x 4 for β -carotene content with means of 12.39

122 mg 100 g⁻¹ and dry matter content with a mean of 30.05% while 2 x 4 had the least β-carotene
123 content and dry matter content with a means square values of 0.03 mg 100 g⁻¹ and 31.15%.

124

125 **3.2 General and specific combining ability analysis for β-carotene content and dry matter** 126 **content**

127

128 General combining ability and Specific combining ability means sum of squares for β-carotene
129 content and dry matter content were highly significant (p<0.01) across the parents, parent x cross
130 and the crosses as presented in Table 6. The mean squares for reciprocals of β-carotene content
131 were significant (p<0.01) whereas mean squares for dry matter for the reciprocal is not
132 significant.

133 **3.3 COMBINING ABILITY EFFECTS**

134

135 **3.3.1 Beta-carotene content**

136 Table 7 presented estimates of GCA effects for β-carotene content and dry matter content of six
137 sweet potato parents. The GCA effects for β-carotene content of parent 1, 2 and 3 were positively
138 and highly significant (p<0.01). The GCA effects for parent 5 is significant (p<0.01) but
139 negative. The GCA effect for parent 4 and 6 were negative and were not significant. The SCA
140 effects of crosses 1 x 2, 1 x 4, 1 x 5, 1 x 6, 2 x 3, 2 x 5, 2 x 6 and 3 x 5 were positive and highly
141 significant (p<0.01) (Table 8) whereas cross 3 x 6, 4 x 6 is also significant but negative. The rest
142 of the crosses are positive and not significant, apart from 1 x 3 which was negative and is not
143 significant (p<0.01). Four reciprocals (5 x 2, 5 x 4, 6 x 5 and 6 x 2) were not significant (p<0.01)
144 and negative except cross 6 x 2 which is positive. Crosses 3 x 1 and 3 x 2 were highly significant
145 although they were negative. The rest crosses were positive and highly significant (p<0.01)
146 (Table 8).

147 **3.3.2 Dry Matter Content**

148
149 The GCA effects for parent 2, 4 and 6 were positively and highly significant ($p < 0.01$). The GCA
150 effects for parent 1 is also significant ($p < 0.01$) but negative. The GCA effect for parent 5 was not
151 significant but positive (Table 7). Crosses 1 x 2 and 3 x 5 were positive although not significant
152 (Table 8). This is against crosses 2 x 3, 3 x 4, 4 x 5 and 4 x 6 which were negative and not
153 significant ($p < 0.01$). SCA effect for the rest of the crosses were significant ($p < 0.01$) and positive
154 (Table 8). For reciprocal, crosses 6 x 1 and 6 x 2 are the only crosses that were positively and
155 highly significant ($p < 0.01$).

156 **4 Discussion**

157 **4.1 General and specific combining ability for β -carotene content and dry matter content**

158 Both GCA and SCA variances were significantly (Table 5), this suggest that both additive and
159 non-additive gene effects played major role in the inheritance of β -carotene and dry matter
160 content. The GCA and SCA mean squares for the β -carotene and dry matter content were
161 significant ($p < 0.01$). This implies that both additive and non-additive gene action were involved
162 in their expression. This study indicates that additive gene action was relatively more
163 predominant than non-additive gene action in controlling the expression β -carotene content and
164 dry matter content. Hence, predicting progeny performance based on GCA for the traits will be
165 largely successful. The highly significant ($p < 0.01$) reciprocal mean squares for β -carotene and
166 dry matter content indicates that maternal effects can play a major role in the inheritance of these
167 traits and consequently the performance of a parent in a cross is dependent on whether it is used
168 as a female or a male.

169 **4.2 β - carotene content**

170 The GCA effects for parent 1 (1.33) and (1.12) were significant ($p < 0.01$) and positive indicating
171 that additive gene action contributed positively to the expression β -carotene content consequently,
172 their cross 1 x 2 is positive (3.28) and significant ($p < 0.01$) SCA effect. This means
173 that the interaction between the parent for the non-additive gene action resulted in the cross
174 performing above the expectation based on additive effects. The crosses that had positive and
175 significant ($p < 0.01$) SCA effects were 1 x 4, 1 x 5, 1 x 6, 2 x 3, 2 x 5, 2 x 6 and 3 x 5 indicating
176 that the non-additive gene action arising from the interaction of the parents contributed positively
177 to the expression of the trait. Parents 5 that had negative GCA effects (- 0.44) produced a cross
178 with a positive (0.022) and highly significant ($p < 0.01$) SCA effect (Table 6). This shows that
179 parents cannot be disqualified solely on the basis of negative GCA effects. In other word, parents
180 with high positive GCA effects did not necessarily produce crosses with the desired
181 performance. The parents used in this study as well as the crosses generated exhibit different
182 level of significant and desirable crosses were obtained from crossing parents with high GCA
183 effects with parents with low GCA effects that is 1 x 5, 2 x 5 and 3 x 5.

184 **4.3 Dry Matter Content**

185 The GCA and SCA mean squares for dry matter content were significant ($p < 0.01$), but the
186 reciprocal mean square was not significant. For the specific combiners for dry matter content
187 parent 3 had a positive GCA and their crosses with parent 1 and 2 given dry matter content of
188 40.01% and 38.20%.

189 **5. Recommendation**

190 It is therefore recommend that:

- 191 1. The parent 1 and 3 identified to be good general and specific combiners of β - carotene
192 and dry matter content should be further intrigressed into other proven cultivatrs in the
193 improvement of β - carotene and dry matter content in sweetpotato.

194 2. The identified crosses with the highest dry matter and β - carotene content could be
195 incorporate into on-farm trial for proof.

196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238

UNDER PEER REVIEW

239 **Table 1: Parental genotypes and their traits used in a 6x6 full diallel excluding selfs**
 240

No	Genotype	Root flesh colour	Root Dry mass (%)	Source
1	199024.2	Orange	31.02	CIP Kenya
2	440034	Orange	26.92	CIP Kenya
3	Excel	Orange	28.53	South Africa
4	W-151	Yellow	34.29	CIP Kenya
5	TIS 87/0087	White	30.67	IITA Ibadan
6	440168	White	32.31	CIP Kenya

241

242 **Table 2. Physical and chemical characteristics of the experimental site soil at Landmark**

243 **University, Omu Aran.**

Physical characteristics	properties
Texture	Loamy sand
pH 1:1 (H ₂ O)	5.4
Sand %	84.1
Clay %	8.02
Silt %	6.42
Chemical characteristics	
Exchangeable Ca ²⁺ (C. mol kg ⁻¹)	1.12
Exchangeable Mg ²⁺ (C. mol kg ⁻¹)	1.62
Exchangeable Na ⁺ (C. mol kg ⁻¹)	0.19
Exchangeable K ⁺ (C. mol kg ⁻¹)	0.01
Total acidity H ⁺ (C. mol kg ⁻¹)	0.05
Cation exchange capacity (C. mol kg ⁻¹)	2.83
% Organic Carbon	0.24
% Soil organic matter	1.03
% Total Nitrogen	0.24
Available Phosphate (mg kg ⁻¹)	20.31

246

247

248

249

250

251

252

253

254

255

256 **Table 3 Analysis of variance for Griffing's (1956b) Model I, Method I and the expected**
 257 **mean squares for a full diallel.**
 258
 259

Source	Df	sum of squares	mean squares	Expected mean squares	F-ratio
GCA	p-1	S_g	M_g	$\delta^2 + 2p[1/p-1]\sum g_i^2$	M_g/M_e
SCA	$p(p-1)/2$	S_s	M_s	$\delta^2 + 1/p(p-1) \sum_i \sum_j s_{ij}^2$	M_s/M_e
Reciprocal effects	$p(p-1)/2$	S_v	M_v	$\delta^2 + 2[2/p(p-1)] \sum_i \sum_j r_{ij}^2$	M_r/M_e
Error	M	S_e	M_e	δ^2	

260
 261
 262
 263
 264
 265

Table 4: ANOVA for six sweetpotato parents and their 30 F₁ families evaluated in a triple lattice design

Source	Df	Mean squares	
		β -carotene content(mg 100 g-1)	Dry Matter content (%)
Rep	1	0.75 ^{ns}	7.85 ^{ns}
Treatment	35	38.39**	34.28**
Block within reps	35	14.1	29.60
Intra-block error	70	0.32	5.10
Total	141		

266 *, ** Significant at ($p < 0.05$) and ($p < 0.01$) (F -probability) respectively; ns=not significant
 267

268
 269
 270
 271
 272
 273
 274
 275
 276

277 **Table 5: Block corrected means for six sweet potato parents and their diallel evaluated**

Parents/Crosses	β -carotene content (mg 100 g ⁻¹)	Dry Matter content (%)
1 x 2	1.5	33.00
1 x 3	14.37	40.10
1 x 4	12.39	30.5
1 x 5	1.32	31.88
1 x 6	3.37	28.43
2 x 3	5.49	38.67
2x 4	0.03	31.15
2 x 5	0.03	27.38
2x 6	1.74	27.27
3 x 4	1.5	29.49
3 x 5	0.12	31.67
3 x 6	1.38	35.71
4 x 5	0.02	37.04
4 x 6	0.03	38.89
5 x 6	1.38	34.15
Reciprocal		
2 x 1	11.03	33.82
3 x 1	4.92	31.86
4 x 1	4.41	29.73
5 x 1	0.12	34.00
6 x 1	1.38	34.78
3 x2	4.92	25.86
4 x 2	0.13	35.00
5 x 2	1.66	32.69
6 x 2	1.50	34.72
4 x 3	6.12	32.56
5 x 3	4.92	28.30
6 x 3	0.03	33.33
5 x 4	1.38	24.49
6 x 4	1.5	33.94
6 x 5	0.03	27.47
Parent 1	13.38	36.25
Parent 2	0.15	32.00
Parent 3	5.49	26.47
Parent 4	0.00	25.86
Parent 5	0.03	29.73
Parent 6	0.12	28.30
Mean	2.86	31.89
s.e	0.39	5.38
CV (%)	15.1	7.01
LSD _{0.05}	0.85	6.04

278

279 **Table 6: Combining ability ANOVA for β -carotene content and dry matter content**

280

Source	Df	Mean squares	
		β -carotene content(mg 100 g ⁻¹)	Dry Matter content (%)
Rep	1	0.65**	7.85 ^{ns}
Parent	5	31.39**	134.28**
Parent x cross	1	11.1**	29.60**
Crosses	11	62.32**	25.10**
GCA	5	83.98**	54.76**
SCA	6	53.76**	10.80**
Reciprocal	12	54.23**	6.9 ^{ns}
Error	100	0.032	7.63
Total	141		

281 ** Significant at $p < 0.01$ (by F -probability); ns=not significant; GCA=variation due to general
 282 combining ability, SCA=variation due to specific combining ability, reciprocal=variation
 283 between reciprocal

284

285

286

287 **Table 7 Estimates of GCA effects for β -carotene content and dry matter content of six**
 288 **sweet potato parents**

Parent	β -carotene content	Dry Matter Content
1	1.33**	-3.41**
2	1.12**	4.38**
3	0.50**	- 2.88**
4	-2.13 ^{ns}	2.05**
5	-0.44**	0.12 ^{ns}
6	-0.355 ^{ns}	1.04**

289 ** Significant at $p < 0.01$ (by F -probability); ns=not significant.

290

291

292

293

294

295

296

297

298

299

300

301

302
303
304
305
306

Table 8: Estimates of SCA effects for the Diallel analysis for β -carotene content and dry matter content

Crosses	β -carotene content (mg 100 g ⁻¹)	Dry Matter content (%)
1 x 2	3.28**	1.64ns
1 x 3	-2.14ns	3.10**
1 x 4	5.16**	0.78**
1 x 5	0.022**	1.88**
1 x 6	3.37**	3.43**
2 x 3	5.49**	-8.67ns
2x 4	0.03ns	1.15**
2 x 5	4.03**	2.38**
2x 6	1.74**	2.92**
3 x 4	1.27ns	-2.49ns
3 x 5	0.12**	1.67ns
3 x 6	-1.38**	3.76**
4 x 5	-0.02ns	-3.04ns
4 x 6	-7.03**	-3.89ns
5 x 6	-1.38ns	3.15**
Reciprocal		
2 x 1	11.03**	-3.82ns
3 x 1	-4.92**	-1.86**
4 x 1	-6.41**	2.73**
5 x 1	-3.12**	3.00ns
6 x 1	1.38**	3.73**
3 x2	-4.92**	-2.06ns
4 x 2	0.13**	-3.00ns
5 x 2	-1.66ns	2.69Ns
6 x 2	5.50ns	3.72**
4 x 3	6.12**	-3.56
5 x 3	4.92**	2.30ns
6 x 3	0.02**	-3.33
5 x 4	-1.38ns	-2.49
6 x 4	1.5ns	-3.94ns
6 x 5	-5.03ns	2.47ns

307
308
309

310

311

*, ** Significant at ($p < 0.05$) and ($p < 0.01$) (F -probability) respectively; ns=not significant

312

313 **References**

- 314 1. FAO. The global potato economy. Int. Year Potato 2008, Trade and Markets Division,
315 FAO, Rome, Italy. 2008; <http://www.fao.org/potato-2008/en/potato/IYP-3en.pdf>
316
- 317 2. Reddy UK, Bates GT, Ryan-Bohac J, Nimmakayala P. Sweetpotato. In: KOLE, C (ed.)
318 Genome mapping and molecular breeding in plants. New York: Springer. 2007; pp. 237-
319 239.
- 320
- 321 3. Jarret RL, Gawel N, and Whittmore A. Phylogenetic relationship of sweetpotato
322 [*Ipomoea batatas* (L.) Lam.]. *J. Amer. Soc. Hort. Sci.* 1992; 117: 633-637.
323
- 324 4. Rees D, van Oirschot Q.E.A, Amour R, Rwiza E, Kapinga R, Carey T. Cultivar
325 variation in keeping quality of sweet potatoes. *Postharvest Biol. Technol.*, 2003;
326 28: 313-325.
- 327
- 328 5. Jones A, Steinbauer CE, Pope DT. Quantitative inheritance of ten root traits in sweet
329 potatoes. *Journal of the American Society for Horticultural Science* 1969; 94: 271-275.
330
- 331
- 332 6. Mukasa, SB, Rubaihayo, PR, Valkonen, JTP. Incidence of viruses and viruslike disease
333 of sweetpotato in Uganda. *Plant Disease* 2003;87:329-335
334
- 335 7. Collins WP. Analysis of growth in Kennebec with emphasis on the relationship between
336 stem number and yield. *American Potato Journal* 1977; 54:33-40.
337
- 338 8. Mwangi ROM, Yencho GC, Moyer JW. Diallel analysis of sweetpotato for resistance to
339 sweetpotato virus disease. *Euphytica* 2002; 128: 237-248.
- 340
- 341 9. Hayman BI. The analysis of variance of diallel table. *Biometrics* 1954a; 10: 235-244.
- 342 10. Hayman BI. The theory and analysis of diallel crosses. *Genetics* 1954b; 39: 789-809.
- 343 11. Hayman BI. The theory and analysis of diallel crosses. II. *Genetics* 1958; 43: 63-85.
- 344 12. Hayman BI. The theory and analysis of diallel crosses. III. *Genetics* 1960; 45: 155-172.
- 345 13. Dickinson AG, Jinks JL. A generalised analysis of diallel crosses. *Genetics* 1956; 41: 65-
346 78.
- 347 14. Griffing B. Concept of general and specific combining ability in relation to diallel
348 crossing systems. *Aust. J. Biol. Sci.*, 1956; 9: 463-493

- 349 15. Mihovilovich E, Mendoza HA, Salazar LF. Combining ability for resistance to
350 sweetpotato feathery mottle virus. *Hort. Science* 2000;35: 1319-1320.
- 351 16. Yan W, Hunt LA. Biplot analysis of diallel data. *Crop Science* 2000;42: 21-30.
- 352 17. Salami AE, Agbowuro GO. Gene Action and Heritability Estimates of Grain Yield and
353 Disease Incidence Traits of Low-N Maize (*Zea mays* L.) Inbred lines *Agriculture And*
354 *Biology Journal Of North America* 2016;Vol. 7 (2) pg 50-54,
355 doi:10.5251/abjna.2016.7.2.50.54
- 356 18. Rojas BA, Sprague GF. A comparison of variance components in corn yield trials: III.
357 General and specific combining ability and their interaction with locations and years.
358 *Agron. J.* 1952; 44: 462–6.
- 359 19. SASInstitute. SAS/STAT user's guide. Version 6,4th ed. 1995 Vol. I and II. SAS Inst.
360 Inc. Cary N.C., U.S.A.
- 361
- 362
- 363
- 364

UNDER PEER REVIEW